Background Paper on Green Infrastructure Development in the Buffalo- Niagara Metropolitan Region

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Abstract

The Buffalo-Niagara metropolitan region drains its Combined Sewer Overflows (CSOs) into Erie Lake, which is the smallest of the Great Lakes in terms of water volume and receives nearly 73 percent of the total untreated CSO volumes discharged into the Great Lakes system. Given that the Great Lakes meet the drinking water needs of 40 million people in the US, preserving water quality of these lakes is of great consequence for a healthy population and strong economy. Hence the quality and quantity control of CSO discharges into these lakes is crucial for the region. This paper examines green infrastructure and its development in the Buffalo-Niagara Region as a CSO management strategy.

The International Joint Commission of Canada and the U.S. and the US Environmental Protection Agency (EPA) have recommended adoption of green infrastructure as a solution to water quality concerns such as eutrophication in the Great Lakes by bringing about CSO abatement and discharge quality control. Discharge quality control includes the reduction of pollutants such as Phosphorus, Nitrogen, metals and pathogens. Through a review of empirical studies, the paper establishes the effectiveness of different green infrastructure practices in reducing the pollutant levels in storm water as well as reducing storm water runoff volumes.

Given this background, the paper explores the development of green infrastructure as a storm water management strategy in the region. Buffalo has an established Green Infrastructure Master Plan, the first of its kind in the region. Choosing Buffalo as a best scenario case in the region, the paper critically examines the strengths and challenges faced in implementation of a green infrastructure based storm water management strategy by the providers – the Buffalo Sewer Authority (BSA) and the City of Buffalo along with partners such as PUSH and Buffalo Niagara Riverkeeper.

Among the major opportunities were:

1. A supportive leadership which included supportive policies and resources extended by the USEPA through the NYS Department of Environmental Conservation (DEC) and the willingness of leaders at the City administration and the BSA to invest in GI as a cost-effective alternative to gray infrastructure.
2. Nurtured awareness and public support by organizations such as Buffalo-Niagara Riverkeeper, the UB Regional Institute and other non-profits about the benefits of GI not just among the general public, but also among the elected representatives, university/college fraternities, professionals and non-profits with overlapping environmental interests helped establish a climate conducive to GI. High levels of awareness among peers induced pressure on authorities to deliver such environmental friendly and cost effective services.
3. Timely introduction and consideration of the GI proposals avoided costs of getting the agencies and partners back to the table which have proved an impediment to the adoption of GI as a municipal agenda in other towns and municipalities.
4. Building on existing opportunities such as the Department of Public Work's demolition and vacant lot reclamation projects and the popularity of the green streets as an urban revitalization strategy in the region improved chances of success.
5. Technical skill and local knowledge engaged extensively in BSA's efforts at planning and implementing the green infrastructure plan.

Among the major challenges identified are early adopter risks at implementing innovative solutions, heavy dependency on local funding sources (which are insufficient) and competitive grant based funding, lack of integrated storm water management decisions across gray and green infrastructure provisioning, across local jurisdictions on CSO quality standards etc. and far from adequate storm water modeling capabilities influencing land use decisions.

The recommendations the paper makes to improve viability of green infrastructure in the region at the regional level are

- Regional Level Integration of Efforts, which include
    - Regulatory Strategies for Improving Collaboration among Local Governments

    - Facilitating information transfer and awareness building among communities
    - Improving standardization of storm water models for the entire watershed to allow inter jurisdictional inputs, while maintaining their flexibility to incorporate site level inputs
    - Integrating green infrastructure into mainstream land use development planning at the regional level.
- Improving storm water system simulation skills and technology
- Improving fund allocations and financing options
- Improving monitoring and maintenance protocols for implemented projects

Introduction

The New York League of Conservation Voters Education Fund (NYLCVEF) is a statewide organization whose mission is to educate, engage and empower New Yorkers to be effective advocates for the environment. NYLCVEF plans to organize a policy forum to assess and disseminate knowledge on the current state and future opportunities related to green infrastructure in the Buffalo-Niagara metropolitan region. This paper, funded by the NYLCVEF, serves as the background document to the policy forum planned for October 2016.

Background

The Buffalo-Niagara region feeds Lake Erie, one of the seven precious freshwater reserves in the US and part of the Great Lakes Basin ecosystem. The Great Lakes Basin ecosystem holds approximately 84 percent of North America's surface freshwater and approximately 21 percent of the world's supply. Given that the Great Lakes meet the drinking water needs of 40 million people[1] in the US, preserving water quality of these lakes is of great consequence for a healthy population and strong economy.

The US Environmental Protection Agency (USEPA) identifies Combined Sewer Overflows (CSOs) as a major pollutant source that impacts the Great Lakes system[2]. CSOs are overflows of wastewater from combined sewer systems[3] during heavy precipitation events, such as heavy rainfall or snowmelt, when the capacity of the sewer system or a treatment plant is exceeded. CSO discharges can introduce bacteria and nutrient concentrations such as phosphorus, metals and nitrogen; among other pollutants; that far exceed the assimilative capacity of the water bodies. Consuming or coming into contact with such contaminated water during activities such as swimming, fishing, cleaning sewers or during incidents of sewage back up into homes pose health risks for humans. CSO contamination of water bodies have associated economic impacts as well.

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[1] Administration, N. O. (2014, June 5). Great Lakes Environmental Research Laboratory. Retrieved from About Our Great Lakes: Great Lakes Basin Facts: http://www.glerl.noaa.gov/pr/ourlakes/facts

[2] U.S Environmental Protection Agency. (2016). Report to the Congress: Combined Sewer Overflows into the Great Lakes Basin. USEPA, Office of Wastewater Management.

[3] A combined sewer system (CSS) collects rainwater runoff, domestic sewage, and industrial wastewater into the same pipe and transports all the wastewater it collects to a sewage treatment plant for treatment, then discharges to a water body.

Reduced water quality can lead to fish kills that affect livelihoods and recreational activities (such as sport fishing); loss of quality of estuarine and shoreline habitats decreasing tourism activity; restrictions on shell fish cultivation etc.[4]; affecting local revenues and income. According to USEPA estimates, the country's annual loss of income from beach closings was between $1-$2 billion, and economic losses due to illness from sewage releases was about $28 billion [5] in 2004. CSO contamination also results in higher costs of water treatment, loss of work hours due to ill health, increased health care costs and depreciation in value of lands adjacent to the polluted water bodies.

In 2009, the Great Lakes Regional Collaboration (GLRC) which created partnerships at the federal, state and local levels to restore and protect the Great Lakes ecosystem recommended[6] the need to prevent introduction of invasive aquatic species and actions such as improvements in discharge controls for CSOs. In the same year, the International Joint Commission of Canada and the U.S. also recommended adoption of green infrastructure as a high potential solution to control and prevent pollutants from municipal sources entering into the Great Lakes System[7]. Incorporating these recommendations into storm water management and land development planning is particularly important for the Buffalo- Niagara region since its CSOs drain into the Erie Lake which receives most, nearly 73 percent, of the total untreated CSO volumes among the Great Lakes in spite of being the smallest in terms of volume of water held.

Given this background, we now try to describe "green infrastructure" and its many established benefits that allow consideration of green infrastructure as a potential solution to CSO problems in the region.

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[4] Agency, U. S. (2007). *Report to the Congress:Combined Sewer Overflows to the Lake Michigan Basin.* USEPA Office of Water.

[5] Canada, I. J. (2009). 14th Biennial Report on Great Lakes Water Quality. Washington D.C.: International Joint Commission Office.

[6] Collaboration, G. L. (2005). Great Lakes Regional Collaboration Strategy to Restore and Protect the Great Lakes. GLRC.

[7] Canada, I. J. (2009). 14th Biennial Report on Great Lakes Water Quality. Washington D.C.: International Joint Commission Office.

Green Infrastructure and its Impacts

According to the EPA, green infrastructure at the city or county scale is a patchwork of natural areas that provide habitat, flood protection, cleaner air and cleaner water. At the neighborhood or residential site scale, it refers to storm water management systems that mimic nature by soaking up and storing water. The 2011 Green Infrastructure Solutions (Draft) Report by Buffalo-Niagara Riverkeeper describes green infrastructure as built systems that mimic natural systems by capturing clean rainwater and maximizing the extent it soaks into the ground water table. Benedict and McMohan (2006)[8] emphasize the cultural value of services offered by green infrastructure when they define it as "a strategically planned and managed network of wilderness, parks, greenways, conservation easements, and working lands with conservation value that supports native species, maintains natural ecological processes, sustains air and water resources, and contributes to the health and quality of life for America's communities and people." Some of the most common land use practices that qualify as green infrastructure are green roofs, rain barrels, large and small scale retention, infiltration basins, porous pavements, green streets, tree planting, forested zones and community gardens[9].

Green roofs refer to rooftops which have a planting medium which grows vegetation and is laid over a waterproofing membrane. Such gardens may also have irrigation and under drains. The planting medium can vary between 2 to more than 6 inches depending on the nature of vegetation intended and the layering of the planting medium. Rain barrels are a means of rainwater harvesting in which storm water from roofs, terraces etc. is captured and channeled into storage barrels. This collected rainwater can be used for irrigation, toilet flushing etc. Large and small-scale bio retention areas generally include wet and dry bio swales, rain gardens and constructed wetlands. Rain gardens[10] refer to landscaped and vegetated rain water collection areas that are strategically

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[8] Benedict, M. A., & McMohan, E. T. (2006). *Green Infrastructure: Linking Landscapes and Communities.* Washington: Island Press.

[9] Buffalo Niagara Riverkeeper. (2011). *Green Infrastructure Solutions to Buffalo's Sewer Overflow Challenge (Draft Feasibility Report).* Buffalo: Buffalo Niagara Riverkeeper., The NY Works for Business. (2013). *Wastern New York Sustainability Plan 2013.*

[10] Natural Resources Conservation Service. (2005). *Rain Gardens.* USDA.

located to intercept runoff from surrounding surfaces. The soil composition in rain gardens allow for filtration and thus treatment of the runoff. Bio swales are deeper retention areas that are designed to convey storm water into the sewer system at a rate that allows the sediments, silt and pollutants to settle and hence get filtered out from the sewer system. They are usually created close to impervious surfaces such as parking lots, roads etc. and their filter layer depths range between 2-3 ft[11]. Constructed wetlands are systems designed to maximize pollutant removal and to control peak flows. These typically comprise of a sediment fore bay, shallow marshes, deeper areas or micro-pools and a water outlet arrangement that usually drains to natural water courses. Their depths may vary from 6 inches in the shallow pockets to 6 feet in deep areas. Infiltration basins are green infrastructure practices which have filtration medium (soils) with high infiltration rates. Although they perform all the functions of wetlands, unlike wetlands, they do not discharge water into surface water courses. All water is drained through infiltration to feed the ground water aquifers. The depth of the filter layer is usually between 6 inches to 12 inches and the maximum ponding depth is 2 ft. A separation of 2 feet is maintained between the base of the filter and the seasonal high water table. Porous pavements are pavements whose surface is designed to allow on site seepage of water from rain or snowmelt without the need for channeling water to drainage pipes. Green Streets are streets designed to improve pedestrian friendliness rather than function as dedicated rights-of-way for vehicular traffic. They are landscaped to improve their quality as open spaces and enhance environmental functions such as storm water collection and infiltration by incorporating features such as tree box planting, pervious surfaces, vegetated strips etc. The potential water system benefits and services of each of these land use practices is summarized in Table 1.

[11] Yocum, D. (2005). *Design Manual: Bilogical Filtration Canal (Bioswale).* Santa Barbara: Bren School of Environmental Science and Management, UC .

Table 1. Water System Benefits of Green Infrastructure Practices

Practice	Reduces water treatment needs	Reduces storm water runoff	Reduced sediment and nutrient load to natural bodies	Increases surface water availability	Increases ground water recharge	Increases recreation opportunities	Improves Habitat	Urban Agriculture
Green Roofs		×				×	×	×
Rain Barrels	×	×		×				×
Bio swales	×	×	×	×	×	×	×	
Rain Gardens	×	×	×		×	×	×	×
Constructed Wetlands	×	×	×		×	×	×	
Infiltration basins	×	×	×		×	×	×	
Tree Planting	×	×			×	×	×	×
Green Streets	×	×			×	×	×	
Porous pavements	×	×			×			

Common benefits of green infrastructure practices include:

- Reduction of sewage overflows into local waterways and waterbodies during heavy precipitation events, allowing for better water resource quality control;
- Positive contribution to conservation of cultural landscapes and cultural assets;
- Property value enhancement;
- Low energy consumption; and
- Improved health due to improved air quality and reduced heat island effects.

In the context of the environmental problems the Great Lakes region faces, two water quality benefits of green infrastructure warrant further discussion. These are the impact of green infrastructure on eutrophication control and its impact on storm water runoff reduction.

Green Infrastructure and Eutrophication Control

Article 4 of the Great Lakes Water Quality Agreement of 2012 directed states, local governments and agencies to implement programs and measures including those with emphasis on pollution abatement, control and prevention; prevention, control and eradication of aquatic invasive species and conservation to restore habitat and protect species.

In the context of Lake Erie, algal blooms – which refer to rapid and excessive growth of phytoplankton and the proliferation of cyanobacteria – are fast growing menaces. Algal blooms are invasive aquatic species because they can be poisonous, inhibit photosynthesis by which aquatic plants derive food and reduce dissolved oxygen supplies in the water bodies which is crucial for sustaining life[12]. Among the major reasons recognized for the proliferation of algae in the Great Lakes is eutrophication or nutrient enrichment of the water bodies, mainly attributed to phosphorus and nitrogen depositions into the lakes[13]. Controlling phosphorus and nitrogen that enters the lake can therefore achieve pollution abatement, control growth of aquatic invasive species and partially restore the habitat of Lake Erie.

Studies on green infrastructure practices and their performance in terms of nutrient reduction achieved have confirmed their potential as a solution to reduce nutrient loads from runoff[14].

A summary of the potential of different green infrastructure practices to treat CSO discharges is given in Table 2.

Table 2. CSO Quality improvements achieved by different GI Practices[15]

Practice	**% Reductions**					
	Sediment load	**Total Suspended Solids**	**Total Nitrogen**	**Total Phosphorus**	**Metals**	**Pathogens**
Green Roofs	L	0	**	**	NA	NA, but low
Rain Barrels	L	Designed for storm water volume reduction and retention, not for nutrient, pollutant, or bacteria removal				
Bio swales	H	70	10-90	20-90	30-80	NA, but low
Rain Gardens	H	90*	30-50	30-90	40-90	NA, but high

[12] Faucette, B., & Ferver, B. (2010). Phosphorus Reduction in Storm Water Runoff. *Sustainable Land Development Today*.

[13] U.S Environmental Protection Agency. (2016, March 3). *Nutrient Pollution*. Retrieved from Harmful Algal Blooms: https://www.epa.gov/nutrientpollution/harmful-algal-blooms#cause

[14] Ahiablame , L., Engel , B., & Chaubey, I. (2013). Effectiveness of low impact development practices in two urbanized watersheds: retrofitting with rain barrel/cistern and porous pavement. *Journal of Environmental Management*, 119-151.

[15] Geosyntec Consultants. (2013). *Storm Water Best Management Practices (BMP) Proposal and Guidance Document.* Boston: Boston Water and Sewer Commission.

Practice	% Reductions					
	Sediment load	Total Suspended Solids	Total Nitrogen	Total Phosphorus	Metals	Pathogens
Constructed Wetlands	H	80*	20-55	40-60	20-85	≤ 75
Tree Planting[a]	M	85	≤ 45	60-70	58-82	NA, but high
Green Streets	Effectiveness depends on the GI techniques built in. Generally good performance in pollutant reduction					
Porous pavements	M	80	80-85[16]	65	NA	NA, but medium

*with pretreatment methods such as vegetated filter strips, hydrodynamic separators etc.

**increases than decreases nutrient load

[a] values correspond to tree box planting technique

Green Infrastructure and Storm Water Runoff Reduction

Storm water runoff is generated when water due to rain and snowmelt events flows over land such as agriculture fields, lawns etc. or impervious surfaces, such as parking lots, paved streets, and building rooftops without soaking into the ground. Storm water runoffs often feed surface water bodies and partly seep into the earth to form base flows or feed ground water aquifers. In the course of its flow over semi pervious and impervious surfaces storm water accumulates pollutants such as heavy metals, ammonia, phosphorus, motor fuel spills, sediments, soluble solids etc. which reduce the quality of water received by the surface or underground water bodies. Eutrophication concerns that the Great Lakes face today are mostly attributed to the deposition of phosphorus and nitrogen discharged into the lakes by storm water entering through point and non-point sources.

In general, the effectiveness of green infrastructure practices in reducing storm water runoff has been established. Empirical studies have shown that green roofs retain 20-95 percent of precipitation depending on the season of the year, summer retention being greater than winter time retention; depth and composition of soil strata and type of vegetation[17]. Though not the most recommended, rain barrels have been reported to achieve up to 20 percent runoff reduction from residential plots in semi-arid regions and were less effective in regions with more precipitation

[16] Agency, U. E. (1999). *Storm Water Technology Factsheet: Porous Pavement.* Washington D.C.: USEPA Office of Water.

[17] https://nepis.epa.gov/Adobe/PDF/P1003704.PDF

events[18]. Rain gardens, though effective show variations in the storm water reductions achieved depending on the soil characteristics. Their performance in terms of storm water reduction varies between 40 percent to above 90 percent[19]. Porous or pervious payments recorded a storm water reduction of the range 50-93 percent[20].

Reductions in storm water runoff transform into benefits such as reduction in CSO events and their magnitudes, reduced treatment volumes and treatment costs as well as increased ground water recharge.

Economic Benefits of Green Infrastructure

Reduction in storm water runoff volumes reduce the risk of floods and hence economic losses due to floods. Run off reduction close to the point of its generation reduces erosion, nutrient and sediment transportation thereby reducing treatment costs and restorative costs of receiving water bodies, banks, shores etc. Aesthetically pleasing and safe water environments add value to adjacent land properties. Green infrastructure practices such as landscaped rain gardens and catchments add aesthetic value to land and consequently increase land value. Residential or lot level green infrastructure practices such as rain barrels and rain gardens can free up more space for housing plots at increased land cost instead of dedicating large catchments or infiltration trenches for storm water capture and filtration. The preference for pervious pavements reduces costs associated with brick paving, asphalt paving etc.

The Water Management Asset Management study conducted by McGraw-Hill, reports aging water infrastructure as the biggest concern that drives water asset management decisions in the U.S (McGraw-Hill 2013). Most of the urban water supply pipes in the country were laid in the late 1800s, the 1920s or just after World War II. Consequently, most of the existing water distribution infrastructure has outlived its useful life and hence needs to be replaced. The cost of restoring and

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[18] Steffen, J., Jensen, M., Pomeroy, C. A., & Burian, S. J. (2013). Water Supply and Storm Water Mangement Benefits of Residential Rainwater harvesting in U.S. Cities. *Journal of American Water Resources Association*, 810-824.

[19] Dietz, M. E., & Clausen, J. C. (2005). A Field Evaluation of Rain Garden Flow and Pollutant Treatment. *Water, Air and Soil Pollution*, 123- 138.

[20] Ahiablame, L. M., Engel, B. A., & Chaubey, I. (2011). Effectiveness of Low Impact Development Practices: Literature Review and Suggestions for Future Research. *Water Air and Soil Pollution*, 4253-4273.

replacing aged water infrastructure over the next 25 years was estimated to be more than 2.1 trillion USD in 2010[21]. Green infrastructure replacements and investments in major cities such as New York and Philadelphia have produced very encouraging results in cost savings achieved. Cost savings on water treatment ran into billions of dollars and the net present value of the green infrastructure was evaluated 20-30 times as much as the net present value of gray infrastructure for the next four decades[22]. Therefore, green infrastructure solutions to aging gray infrastructure has definite appeal for a sustainable future.

Reduction in storm water runoff to tributary streams, creeks and rivers will reduce public health risks thereby reducing health costs and loss of work hours. These improvements add value of the ecosystems as cultural assets; thereby improving the quality of life for dependent communities. Attempts at quantifying storm water runoff benefits and costs have led to the creation of evaluation tools for some of these green infrastructure practices. Some of the free and readily accessible tools that can measure the price savings, storm water reduction or energy savings of incorporating green infrastructure options are tabulated below.

Table 3: Models and Calculators to Measure GI Impacts[23]

Model or calculator name	Link
Delaware Urban Runoff Management Model	http://www.dnrec.state.de.us/dnrec2000/Divisions/Soil/Stormwater/New/DURMM%20Release%20
CNT's *Green Value Calculator*	http://greenvalues.cnt.org/national/calculator.php
EPA's *Green LTCP-EZ*	http://www.epa.gov/npdes/pubs/final_form_green_ltcpez.xls (Spreadsheet)
USDA Forest Service's *i-Tree*	http://www.itreetools.org/hydro/index.php
EPA's *National Storm Water Calculator (Version 1.1)*	https://www.epa.gov/water-research/national-stormwater-calculator

[21] American Water Works Association. (2010). *Buried No Longer: Confronting America's Water Infrastructure Challenge.* AWWA.

[22] Talberth, J., Gray, E., Yonavjak, L., & Gartner, T. (2013). Green versus Gray: Nature's Solutions to Infrastructure Demands. *Solutions*, 40-47

[23] Agency, U. E. (2015). *Green Infrastructure: Models and Calculators.* USEPA.

Local Government Environmental Assistance Network 's *Long-Term Hydrologic Impact Assessment Model*	http://www.ecn.purdue.edu/runoff/lthia/lthia_index.htm
UW Madison's *RECARGA*	http://dnr.wi.gov/topic/stormwater/standards/
EPA's *SWMM*	https://www.epa.gov/water-research/storm-water-management-model-swmm

Current State of Green Infrastructure Development in the Buffalo-Niagara Region

Green Infrastructure Development Status

We now discuss the case of Buffalo city to understand the opportunities and challenges for Green Infrastructure as experienced by the major implementers and managers in these cities.

Storm water management in the city of Buffalo is the responsibility of the Buffalo Sewer Authority (BSA), a public benefit corporation of New York. The BSA has exclusive jurisdiction, ownership, and possession of the sewage collection and treatment system that serves the City of Buffalo and specific adjacent communities.[24] The BSA's mandate is separate from the City of Buffalo. The BSA owns and operates a combined sewer system which includes a secondary treatment plant located on Bird Island, a collection system of sewer lines and 52 permitted CSO outfalls. To comply with the CSO control policy of 1994, the New York State Department of Environment Conservation (NYSDEC) required that a Long Term Control Plan be created for the CSS managed by the BSA. The Long Term Control Plan was first submitted to the NYSDEC and the USEPA in 2004 and finalized after a series of inputs and revisions in 2014.

Summary of the Long Term Control Plan

Estimated at 380 million dollars, the Long Term Control Plan[25] (LTCP) for the City of Buffalo has been conceived in three phases with an implementation period of 20 years. Development of

[24] ARCADIS; Pernie, Malcolm;. (2014). *LTCP Appendix 12.3: Green Infrastructure Master Plan.* Buffalo: Buffalo Sewer Authority.

[25] Authority, B. S. (2009-2016). *January 2014 LTCP*. Retrieved from Buffalo Sewer Authority: http://bsacsoimprovements.org/cso-control-plan/january-2014-ltcp/

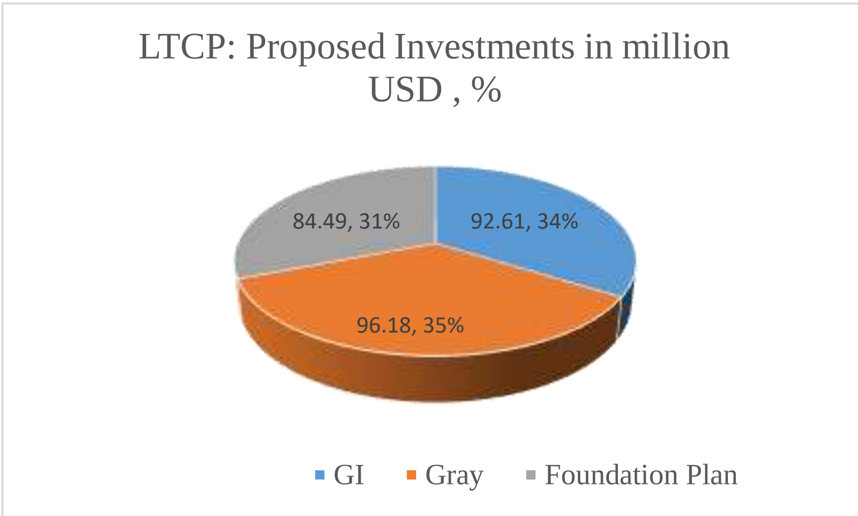
the plan was guided by the objectives of achieving water quality standards stipulated under the Clean Water Act, CSO abatement and development of water modeling capabilities to evaluate CSO abatement options. The LTCP primarily focuses on collection system improvements. The foundation plan identified a set of controls to be implemented on a priority basis, that were likely to be part of the final LTCP even if a need for LTCP update arose. Between 2004 and 2014, the earlier foundation plan was revised to accommodate a switch in the management strategy of the BSA, from sewer separation as a primary control strategy to a combination of low-cost system optimizations including GI and real time control (RTC) projects. Of the four development alternatives considered for the LTCP, alternative UA2 which includes GI elements was adopted. Though some sewer separation projects are still being implemented as part of the revised Foundation Plan and the Phase 1 projects proposed in 2004, the UA2 alternative does not include any project proposals for sewer separation. Extent of compliance achieved with the Water Quality Standards of the Clean Water Act, affordability and cost effectiveness were the major criteria that led to the selection of the GI based alternative for the LTCP. The BSA investments in completed and ongoing construction projects in Phase 1 is over $50 million.

The recommended plan for development includes

- a revised foundation project which will aim at low cost system optimizations, cost effective real time control projects and pilot GI projects.
- Gray infrastructure projects with major focus on increasing offline storage capacities of the sewer system.
- Green infrastructure projects which include vacant and demolition site restoration, pervious pavements and green streets, rain gardens and spout disconnections as well as rain barrels. GI implementation assumes control of up to 20 percent of impervious surfaces within selected sewer sheds. The land is assumed to be public owned following directions from the DEC.

The proposed investments across the gray infrastructure, green infrastructure and Foundation plan components are illustrated in Fig 1.

Figure 1. Proposed Investments in LTCP



Review of the Green Infrastructure Master Plan

The UA2 alternative that BSA adopted for the LTCP was the only alternative with GI emphasis. Following the requirement of the NYSDEC and the USEPA on the LTCP, details of the green infrastructure component were worked out to generate the Green Infrastructure Master Plan. The plan will be implemented in phases. A summary of the Phase 1 projects is provided in Table 4. The subsequent phases were conceived as building upon the success and learnings of Phase 1 since an attempt at the Green Infrastructure Master Planning is the first of its kind in the region. Phase 1 projects have a five-year completion timeline and include vacant lot management and demolitions along with seven green streets projects.

Table 4: Phase 1 Projects of the BSA's Green Infrastructure Master Plan

Project Type	Description	Impervious acreage applied to targeted CSO control	Cost estimates ('000 USD)
Demolitions and Vacant Lot Management	2001 – 2013 Demolitions	210	0
	CSO 53 Pilot Project and 2014-2018 Demolitions	31	1,448
	Fillmore Ave green lots	0	62
	PUSH Blue Projects	10	0
Green Streets	Fillmore Ave porous parking lots	0.4	15.5
	Ohio Street	2.1	0

	Carlton Street porous asphalt	0	396
	Kensington Avenue	2.5	473
	Kenmore Avenue	4.1	532
	Allen Street	2.5	251
	Niagara Street	14.3	3,250
Total		**267**	**6,427**

The estimated cost to the BSA on these projects is nearly $6.5 million. 60 percent of the targeted 448 acres of impervious area control applies to targeted CSO controls. The demolitions and vacant lot management component contributes to more than 90 percent of the targeted CSO control acreage. Major partners in the GI Phase 1 implementation are PUSH and the Public Works Department of the city. The Green Infrastructure Master Plan details out the evaluation criteria and procedure followed for quantifying the impacts of the various GI installations and also spells out the post construction protocols for monitoring and performance assessments. However, calculations of impact assume a 0.9” deep design storm condition. Given the noticeable changes in precipitation conditions over the past decade, the model may be recalibrated for more recent and representative storm conditions. Impacts are modeled as a function of the amount of impervious area converted to pervious, assuming standard infiltration rates and design parameters for the various GI technologies applied to the green streets projects and the demolishment and vacant site projects. As discussed earlier the effectiveness of particular GI technologies such as rain gardens, green roofs, infiltration trenches etc. depends on the composition of the media and layer depths. Assuming standard dimensions for every GI technology introduces inaccuracies in estimations, the sub catchment wise lumping of GI technologies and assigning storage nodes to each sub catchment oversimplifies the actual drainage characteristics of these sub catchments and the contributions of specific GI technology interventions to reducing storm water runoff. It also fails to explain why relatively small areas of GI intervention resulted in huge changes in CSO reductions. For demolition sites, residential and commercial categories are considered, however parcel-specific information is not available or utilized in the model. The model assumes 65 percent imperviousness for all residential plots and standard proportions of imperviousness corresponding to the basic land use for all commercial properties. Predictions of storm water reductions for future demolishment sites assume identical site development conditions which may not be accomplished.

Targeted CSO benefits and Current Progress

The performance of the GI in managing CSO event frequencies and managing storm water volumes in general is evaluated in terms of CSO volume reduction and CSO event reductions. Projects in Phase I are expected to reduce CSO discharge volumes by 10 percent. The targeted benefits in terms of CSO volume reductions for the different receiving waters fed by the 52 CSO outfalls are as shown in Fig. 2. CSOs into the Buffalo river are expected to reduce most, while the Erie basin discharges will be affected least. In terms of impacts on CSO event frequency, the predicted benefits are summarized in Fig. 3. BSA has an internal target of 6 CSO event reductions per year. It is found that reduction in CSO event frequencies will be most for Black Rock Canal followed by Buffalo River and Cazenovia creek- C. No reductions in CSO events are predicted for Scajaquada Creek, Cornelius Creek or the Erie basin.

Figure 2: CSO Volume Reduction Predicted from Phase 1 Projects

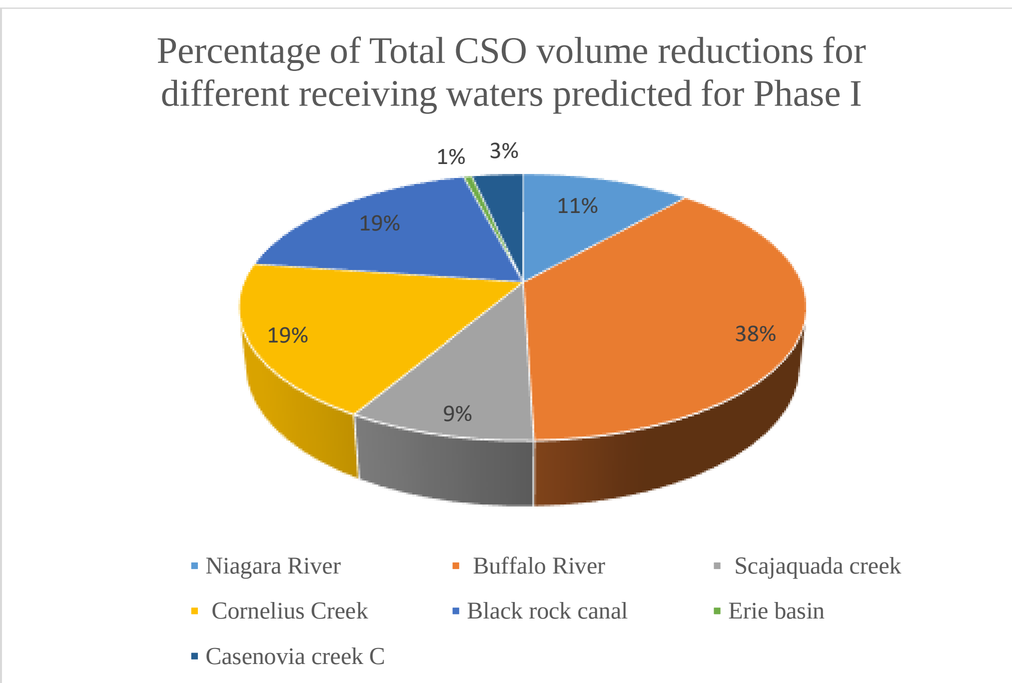
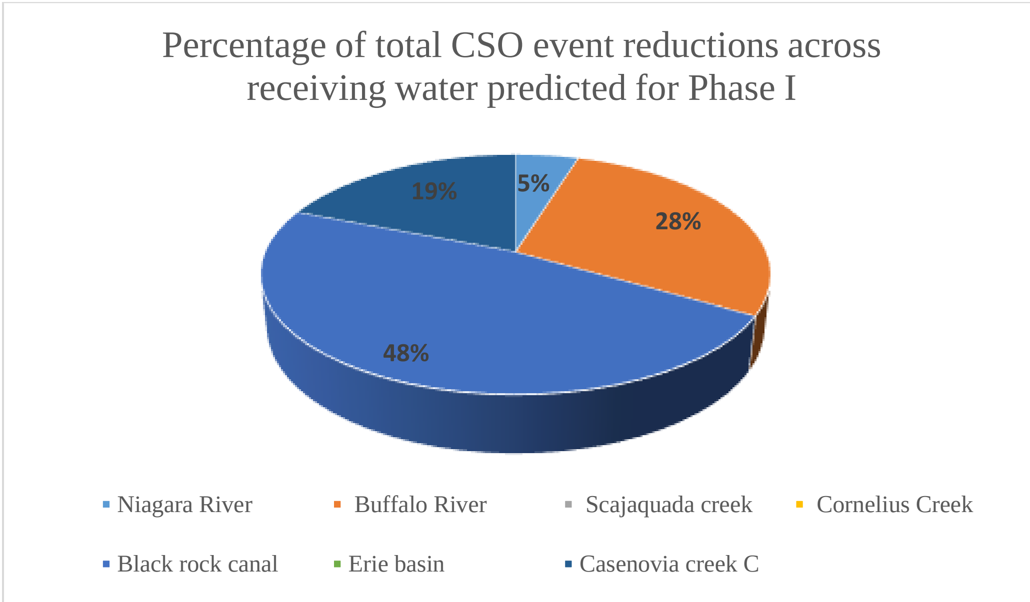


Figure 3. CSO Event Reductions Predicted from Phase 1 Projects



The status on Phase 1 projects is summarized in the table below. Of the Phase 1 projects, the status of the demolition and vacant lot projects is unknown.

Project group	Project	Status (as on 31 July 2016)
Green Streets	Carlton street porous asphalt	completed
	Fillmore Ave porous parking lots	completed
	Ohio Street	completed
	Kenmore Avenue	Nearing completion
	Kensington Avenue	NA
	Allen Street	Getting started, design completed
	Niagara street	Being implemented, entering Phase Three

A comparison of achieved green infrastructure performance from site performance studies conducted by the University of New Hampshire and the Center for Watershed Protection is presented in Appendix 1.

Opportunities and Challenges for Green Infrastructure development

The significant opportunities that the BSA has had in GI development were identified as follows.

1. *Supportive Leadership:* The state and regional regulatory agencies such as the US EPA and the NYSDEC have been mostly supportive of BSA's efforts at GI development. At the policy level, support has been extended in terms of an acknowledgement of GI as a means of achieving Water Quality compliance and sanctioning the LTCP alternative which includes GI development. Given the nascent stage of GI integration into mainstream land use planning, funding opportunities for early adopters and first time adopters through the State Revolving Funds, the Green Innovation Grant Program and the American Reinvestment and Recovery Act have benefitted the BSA. At the local government level, the willingness of leaders at the City administration and the BSA to invest in GI as a cost effective alternative to gray infrastructure was crucial to the GI planning process.
2. *Awareness and Public Support:* The work of Buffalo- Niagara Riverkeeper and other non-profits in building awareness about the benefits of GI not just among the general public, but also among the elected representatives and among non-profits with overlapping environmental interests helped establish a climate conducive to GI in Buffalo. Initial attempts by environmentally active non-profits and the variety of communities they engaged with, including the sewer authority helped create a broad network of support for GI as a cost effective and environmental friendly storm water management practice. These networks also helped maintain pressure on the authorities to opt for GI as a strategy in the city's Long Term Control Plan.
3. *Timeliness of the proposals*: The GI option was presented to the USEPA and the NYSDEC during the rounds of feedback and revisions that the 2004 version of the LTCP underwent. The timely introduction of the alternative avoided costs of getting the agencies and partners back to the table which have proved an impediment to the adoption of GI as a municipal agenda in other towns and municipalities. Such a timely consideration of GI as a storm water management strategy was made possible due to opportunities for knowledge transfer among people who had experience with GI practices in the region such as the Buffalo Niagara Riverkeeper and the decision making/sanctioning authorities.
4. *Building on existing opportunities and public preferences:* The BSA chose to partner with departments that had overlapping interests in land use development. They built on existing opportunities and strengths such as the Department of Public Work's demolition and vacant lot reclamation projects and the popularity of the green streets as an urban revitalization

strategy. Such a careful choice of projects for Phase 1 improved chances of success for GI by reducing project launching costs and gaining the confidence of the communities in the impact of GI on property value and aesthetic improvements.

5. *Technical skill and local knowledge:* BSA's efforts are guided by partnerships with highly skilled teams such as water system consultants, environmental consultants, lawyers and the University at Buffalo apart from organizations that have a presence in the communities such as Buffalo- Niagara Riverkeeper, PUSH and others.

The major challenges for green infrastructure development include:

1. *Early adopter risks and inhibitions to innovate.* Although the BSA is interested in expanding its projects to include tree planting and private partnerships, building confidence of the community and the regulatory agencies on GI success has limited its Phase I plans to green streets and vacant lots and demolition sites. Lack of institutional long term controls on new practices such as tree planting have also crippled the BSA.
2. *Performance measurement and input/ output definitions for modeling:* Modeling capabilities are far from perfect in terms of their measurement of program effectiveness and their representation of land characteristics or GI technology prototyping. Improvements are critical to accuracy of cost benefit analysis that informs land use decisions.
3. *Integrated Sewer System Management lacking:* Measuring effectiveness of GI interventions does not consider system performance enhancements by gray infrastructure upgrades. Institutional structures for governance do not incentivize collaborations across local governments to achieve common water quality goals within the same watershed.
4. *Funding heavily dependent on Municipal or local sources:* Although funding assistance is available from federal and state sources, such as the State Revolving Funds program and the Green Innovation Grants program; it is the local payers who fund most CSO control projects including green infrastructure projects undertaken by the Municipality or sewer authorities. Therefore, CSO control programs represent a significant municipal investment that competes with other local programs.

Recommendations

1. *Regional (watershed) level integration of efforts*
    - *Regulatory Strategies for Improving Collaboration among Local Governments*

Currently NYSDEC issues permits for all point sources that drain into surface or ground waters in each sub watershed and for all treatment plant operators. In order to promote collaborative efforts across the entire watershed to ensure that storm water quality at the CSO outfalls meet WQ standards, strategies to issue collective permits which hold sub watersheds accountable for the discharge quality from their jurisdictions must be devised. Collective permits would also reduce time investments on issuing permits and checking compliance. This can lead to a win- win situation that reduces pressure on the regulatory agencies which are understaffed and builds an incentive for water quality compliance and inter government collaboration at the local level. Grant funding for GI at watershed or sub water shed levels can incentivize co-operation and commitment among local governments.

- *Facilitate information transfer and awareness building among communities*

Ensure easy access to information among citizens through online databases and project repositories of Best Management Practices maintained for the entire watershed, technical guidelines on GI installation at private lot levels and access to real time information on storm water quality and event reductions achieved at mini watershed levels. Allow local governments to monitor the performance of the sewer system at the larger watershed level on a real time basis, to be aware of impacts on outfall discharge qualities downstream due to upstream interventions and to moderate action.

- *Improve standardization of stormwater models for the entire watershed to allow interjurisdictional inputs, while maintaining their flexibility to incorporate site level inputs.*
- *Integrate Green Infrastructure into Mainstream Land Use Development Planning*

Even though the benefits of green infrastructure as an alternative to gray infrastructure and land revitalization have been established, an inductive content analysis of available development plans at the Municipality, County and State levels reveal a neglect of green infrastructure as a strategy in land use development planning in the Western New York (WNY) region. Hence it is recommended that green infrastructure be integrated as a land use development strategy at the various levels of development planning in the NYS to improve its viability as a cost effective and environment friendly solution to restoring our aging gray infrastructure.

2. *System simulation skills and technology*

Improve sensitivity of the current BSA SWM Model in impervious area measurements at lot levels, account for land characteristics such as vegetation, soil composition etc. and existing infrastructure conditions such as pipe layouts and capacities, connectivity to sewers, gray infrastructure upgrades etc. Improve triple bottom line benefit analysis capabilities. Train existing staff or recruit staff with expertise in water systems modeling and collaborate with locally established organizations with water systems modeling skills to inform water systems decisions within the local government jurisdiction.

3. *Funding Support and Assistance*

Financing options such as competitive grants put the less informed and often poorer communities at a disadvantage increasing development inequities. Since maintaining storm water quality is a federal mandate, the Clean Water State Revolving Funds (CWSRF) must identify incentive mechanisms to improve participation by the low compliance communities. These could involve better provisions for subsidized funding or additional perks to larger and better off communities that adopt or assist components of storm water management in neighboring towns or municipalities.

4. *Establish Monitoring and Maintenance Protocols*

There is a requirement for clear protocols at municipal and town levels to ensure sustained performance of GI installations. Currently the success of most installations on public lands is determined by voluntary community ownership. The role of the local government is still not well defined. Since there is a general expectation of community initiated maintenance, GI facility design processes and their installation must ensure community engagement and buy in before implementation. At the level of private land owner incentives in terms of subsidized costs of installation or replacement for those who comply with maintenance standards, periodic inspection by the city etc. can improve maintenance levels.

Appendix 1: Percentage Reductions Achieved on Select Parameters across GI Practices

GI Practice	Reference	% reductions achieved				
		Total Suspended Solids	Total Nitrogen	Total Phosphorus	Bacteria	Peak Flow volume
Bio- swale	UNH[26]	58	-	-	-	52
	CWP[27]	81	56	24	-25	-
Retention ponds (rain gardens)	UNH	87-97	-	34	-	75-79
	CWP	80	31	52	70	-
Gravel Wetlands	UNH	99	-	56	-	87
	CWP	72	24	48	78	-
Porous streets	UNH	97-99	-	60	-	82
	CWP	89	42	65	-	-
Tree planting	UNH	93	-	-	-	-

[26] University of New Hampshire Storm Water Center. (2010). *2009 Biannual Report.* University of New Hampshire.

[27] Protection, C. f. (2007). *National Pollutant Removal Performance Database: Version 3.* Ellicott: Center for Watershed Protection.