Environmental Finance Center

Holistically Analyzing the Benefits of Green Infrastructure

Guidance for Local Governments

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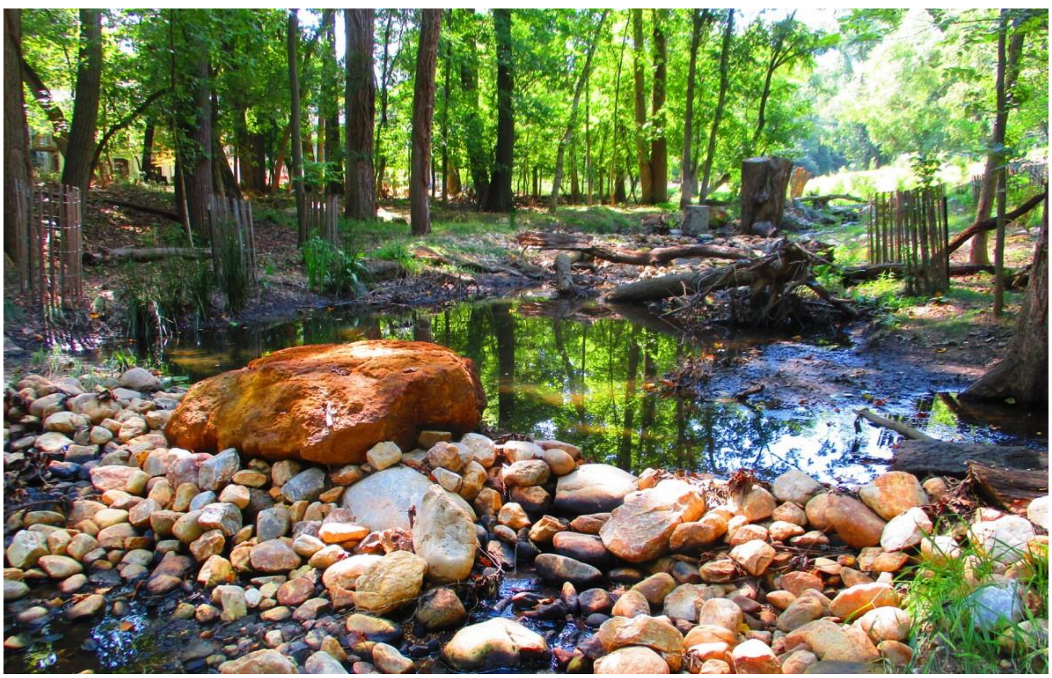

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Cover photograph: Broad Branch DC Stream Restoration.

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Introduction

Changes in the regulatory landscape, coupled with budget-constrained environments, are driving local governments to search for new or evolving strategies and investments that deliver more value than conventional stormwater management practices.

In light of this challenge, green infrastructure (GI) is getting more attention as a stormwater management strategy. GI is described as a more holistic and multifunctional approach to stormwater management that can deliver benefits across the triple bottom line, mitigate water quality impacts, improve quality of life and enhance climate resiliency (US EPA, 2015).

The list of direct and indirect benefits arising from GI is fairly consistent across sources, but the scale and value of these benefits are not. Careful examination of peer-reviewed published literature, combined with existing guidance documents and studies, provide options for quantifying and monetizing the wide array of GI benefits. The various sources are diverse. They employ different valuation and assessment methodologies. Existing resources do not provide a unifying framework or standardization. Consequently, the methods require multi-disciplinary technical knowledge (engineering, economic and bio-physical) that stormwater managers do not generally have.

This document is intended for smaller local governments with stormwater programs that are responsible for regulatory compliance with municipal separate storm sewer system (MS4) obligations (eg, Phase 2 communities). It outlines an approach to holistically evaluate the benefits of implementing green infrastructure. The guidance places emphasis on first understanding the goal and scope for assessing benefits. It uses the goal and scope to step the user through: (1) differentiating between direct benefits and co-benefits of GI, and (2) understanding when and how these benefits need to be characterized, quantified or monetized. This document is not intended to be a “how to” measure benefits for conducting benefit-cost analysis, but rather an approach to tailor benefits and co-benefits identification and description to inform decision making and stakeholder engagement.

The report is organized into three sections with attachments.

- The first section introduces the concept of green infrastructure and describes some of the most common GI practices.
- The second section discusses the range of benefits and co-benefits often attributed to GI.
- The third section outlines an approach to assessing the benefits.
- Finally, the attachments provide case studies that illustrate how this guidance can be used.

Defining Green Infrastructure

While a universal definition of green infrastructure does not exist, a few consistent themes emerge that help solidify the concept of green infrastructure. (The next page offers a few examples of GI definitions for comparison.) In the context of stormwater management, it is an approach that:

- employs a decentralized network of practices
- mimics natural processes
- uses vegetation and soils
- captures and infiltrates rainfall where it falls.

Green infrastructure can involve designed and engineered systems (eg, green roof) or utilize existing natural capital (eg, urban forests and riparian buffers). It is an adaptable approach that can be used at different scales. At small scales, GI can be a single practice, treating an individual parcel or area. At its broadest, GI is a “network of green space that conserves natural systems and provides assorted benefits to human populations” (NJAES).

GI is often used interchangeably with low impact development (LID). GI and LID have common objectives. Similar to GI, LID practices have the objective of minimizing environmental impacts by emulating natural environment and reducing its consumption or use of natural resources. However, LID is a broader term for a planning tool that incorporates GI within planning, zoning, development or regulatory processes.

MANY DEFINITIONS OF GREEN INFRASTRUCTURE

“ Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that … uses vegetation, soils and other elements and practices to restore some of the natural processes required to manage water and create healthier urban environments.” – US EPA

“ Green Infrastructure encompasses a variety of technologies that replicate and restore the natural hydrologic cycle and reduce the volume of stormwater entering the sewer system… How does green infrastructure work: infiltrate (allowing water to slowly sink into the soil); evaporate, transpire and reduce energy consumption by using native vegetation; capture and reuse rainfall…” – PA Dept. of Conservation and Natural Resources

“ Green infrastructure includes a range of soil-water-plant systems that intercept stormwater, infiltrate a portion of it into the ground, evaporate a portion of it into the air, and in some case release apportion of it slowly back onto the sewer system.” – Philadelphia Water Department

“ Green infrastructure (GI) is a network of decentralized stormwater management practices, such as green roofs, trees, rain gardens and permeable pavement, that can capture and infiltrate rain where it falls, thus reducing stormwater runoff and improving the health of surrounding waterways.” – CNT and American Rivers

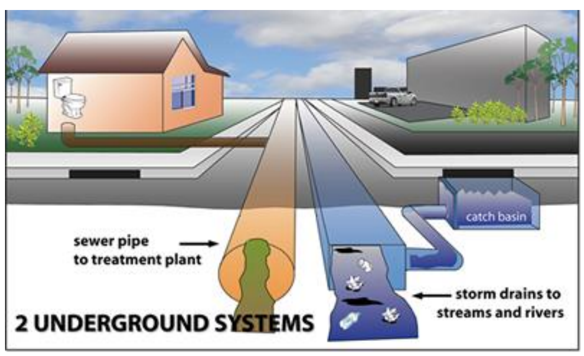
“ Green infrastructure refers to natural or semi-natural ecosystems that provide water utility services that complement, augment or replace those provided by grey infrastructure.” – United Nations Environment Programme

Grey and Green Approaches to Stormwater Management

For MS4 communities, traditional stormwater management may begin with grey infrastructure that may be quite old, dating back to when the area was first urbanized. The grey infrastructure is designed as a set or network of man-made structures that collect stormwater and/or convey it, as quickly as possible, away from the built environment, and discharge it to waterways, such as streams, rivers and lakes. (See next page for examples of grey infrastructure often found in MS4 stormwater inventories.)

Depending upon the age and development characteristics, this collection of infrastructure can be separated or combined with a sanitary sewer system. Combined systems are often found in old cities. These systems transport the collected stormwater and sewage in the same pipe to a sewage treatment plant. Heavy precipitation events can overwhelm the systems, leading to overflows of excess wastewater. Called combined sewer overflows (CSO), these events result in untreated human and industrial waste, in addition to stormwater, being discharged directly to local waterways.

In developed settings with separate storm sewer systems, stormwater infrastructure may also involve underground pipes. The stormwater sewer pipes collect stormwater from street inlets and (residential and commercial) building downspouts and then discharges stormwater to a receiving waterway through an outfall.



Source: www.stormwatersmart.org/Images/2_systems

For more suburban or rural areas, primary stormwater conveyance may be roads (either state or municipally-owned), ditches, and culverts, reflecting the spread and sprawl of commercial and residential development. In addition to the conveyance systems, municipal stormwater assets will often involve outfalls and regional or large-scale facilities, such as basins, wetponds and sandfilters that have been retrofitted to development predating stormwater regulations.

GREY STORMWATER INFRASTRUCTURE

- Municipal streets and roads: public ways designed for motor vehicle traffic that is owned by local government rather than state or federal agencies.
- Curb: generally concrete or stone edge to a street, road or path.
- Gutters: component of a building's rainwater discharge system designed to channel rainwater away from a building's exterior walls and foundation.
- Channel: a constructed, permanent waterway designed to transport surface (stormwater) runoff, commonly found in urbanized areas and along roads.
- Swales and ditches: flow paths greater than 2" in depth which covey concentrated stormwater flow.
- Outfall pipes: structures where stormwater exists or discharged from a piped conveyance system.
- Culverts: structures through which convey permanent non-ephermal water bodies through road embankments or other obstructions.
- Catch basins: inlets through which surface stormwater enters a piped conveyance system.
- Pipe inlets: structures where concentrated stormwater water flow enters the piped conveyance system via horizontal or nearly horizontal pipe in the absence of a catch basin.
- Detention basins/ponds: bermed or excavated areas designed to hold and detain peak stormwater flows caused by impervious surface.

Source: ://www.fairfaxcounty.gov/dpwes/images/stormdrain/outfall.jpg

Grey stormwater infrastructure is a “grandfathered” and vital part of urban and developed areas. Green infrastructure helps naturalize and improve the capacity or function of existing stormwater infrastructure. It provides a potentially effective and integrative approach to managing and/or augmenting existing municipal assets, be it stormwater, parks, buildings or roads. Its potential to offer direct and ancillary benefits depends upon how GI interacts with existing stormwater practices and the built environment around it.

While discussion of grey and green infrastructure often presents the two approaches as an “either-or” decision, the practical reality is that they are complementary. The decision for many municipalities is not between grey or green approaches. Instead, it is about *what is the best approach* to managing stormwater given:

- the purpose of the stormwater investment
- the site location characteristics – including citizen concerns
- capacity to maintain the practice (eg, how well aligns with utility practices and municipal public works approach to operation, maintenance and budgeting)
- budget / financial constraints.

Left: Street inlet; Right: Outfall pipe discharging directly to a stream.

GREEN AND GREY INFRASTRUCTURE FOR STORMWATER: DIFFERENCES

Green infrastructure complements traditional approaches but offers a distinctly new approach to controlling stormwater. It differs from grey infrastructure in three ways.

- GI (used in place of grey) is characterized by the absence of hard engineering which uses concrete, pipes, pumps or other materials to move water away from urban areas.
- GI treats stormwater *where it falls* rather than collecting and conveying it away as efficiently as possible. Contrasting from grey, it offers a system of diffuse and "softer" materials that allow reconnection with natural hydrology (water movement in the land).
- Using natural and semi-natural processes, GI delivers a range of social, environmental and economic benefits that enhance the livability and quality of the built environment and communities.

INTEGRATING GREEN AND GREY INFRASTRUCTURE FOR STORMWATER: AN EXAMPLE

For many communities, GI is used in combination with existing grey infrastructure. For example a wetpond may include wetlands and treeplanting. The picture to the left shows how vegetated shoulders help filter and slow stormwater running off of the road, sidewalks and other impervious surfaces before entering into the storm sewer system.

Examples of Green Infrastructure Practices

Green infrastructure is typically defined through approved engineering practices which have the ability to replace, augment or complement grey infrastructure. The list of stormwater practices identified or recognized as GI depends on the level of analysis by stormwater regulatory agencies in a locality. Guidance documents tend to identify GI practices based on whether they retain, infiltrate, or reduce pollutants from stormwater.

The following offers a sample of common GI practices and serves as an introduction to the concept:

v bioretention and infiltration practices

v green roofs

v green streets and alleys

v permeable pavements

v riparian buffers, stream restoration and tree canopy.

Recommended sources for further information can be found at the end of this section.

Left: Rain garden, City of Cambridge, MD; Right: grassed swale; source: chesapeakestormwater.net/wp-content/uploads/2014/06/UFS2.jpg

Bioretention and Infiltration Practices

This category includes bioswales, planter boxes, rain gardens, and constructed wetlands. These BMPs are designed to:

- collect water from adjacent impervious surfaces
- slow stormwater flows
- filter stormwater through layers of mulch, soil and plant root systems
- allow runoff to be slowly absorbed into the ground.

These practices often complement, replace or augment catch basins and pipes and can be built to different scales. They involve a shallow depression that is planted with trees, shrubs or native vegetation. Swales tend to be more channelized, while bioretention systems will often include a drain system.

Top: Rain garden at City Hall, Edmonston, MD. Bottom: Bioretention retrofit, added to existing parking lot islands with conventional inlets. Source: www.ence.umd.edu/~apdavis/Bioinstallations.htm

Green Roofs

Green roofs are roof tops covered with a growing medium and vegetation. The roof top can be partially or entirely covered. Depending upon the depth of the growing media, the green roof is either extensive or intensive. Extensive green roofs have a shallower growing medium (between two and six inches); intensive green roofs have a growing media depth greater than six inches that allows them to support larger plants. Green roofs help trap precipitation, preventing it from entering storm sewer systems and waterways. The rooftop vegetation mitigates heat island effect and acts as insulation, reducing a building's energy demands for heating and cooling.

Green roofs help reduce an urban area's impervious surface and reduce the amount of stormwater runoff draining into sewer systems. Within densely developed settings, they represent an "additional" area for siting BMPs (ie, outside of right of ways and high traffic areas). At the same time, they can enhance the amenity value of properties through their aesthetic appeal and contribution to a structure's thermodynamics.

Green Streets and Alleys

Green streets are constructed within the street right of ways. It is not a single BMP, but rather a combination of green infrastructure practices that enhance the stormwater management of a street or alley. In many situations, green streets are easier to incorporate in "new development," as opposed to street retrofits.

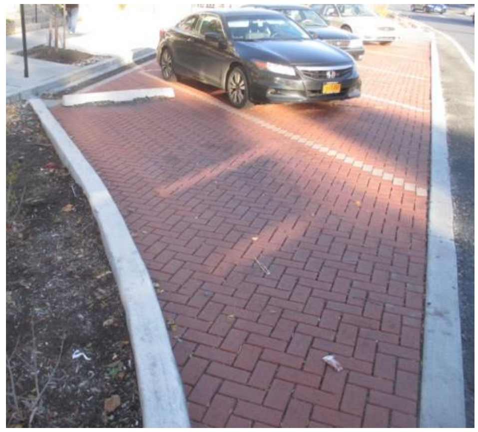
Common GI practices integrated in green street designs are:

- permeable pavement
- rain gardens
- tree boxes
- curb extensions
- grass swales.

In more comprehensive designs, a green street moves beyond addressing stormwater (reducing the amount of impervious). It is explicitly designed to enhance and expand the street's overall functionality and presence. Common improvements include:

- creating an appeal of the streetscape
- facilitating pedestrian movements
- calming traffic.

Depending upon scale, green streets and alley can also provide natural habitat for pollinators and birds.



Permeable Pavements

Permeable pavement provides the hard surface needed for streets, parking lots, and sidewalks while also allowing for precipitation to be absorbed and infiltrated onsite. It includes porous concrete, porous asphalt, and permeable pavers.

Generally, permeable pavement is thought to be more expensive that traditional impervious surfaces. However, they also expand the services that the area provides. In addition to supporting desired aestheics, this practice can economize on space by reducing or avoiding the need for grey stormwater practices, such as detention basins. US EPA notes that permeable pavements are cost effective where land values are high and flooding or icing is a concern.

Riparian Buffers, Tree Plantings and Stream Restoration

This category of GI focuses on natural areas that often require protection or restoration. They include riparian buffers, tree plantings, and urban tree canopy.

Riparian buffers are vegetated areas next to waterways. They protect waterways against erosion and filter pollutants conveyed in runoff from surrounding uplands. Buffer width, in conjunction with vegetation type, affects the extent to which riparian buffers can deliver water and habitat quality benefits.

Tree plantings and urban tree canopy. Tree plantings and the protection of existing mature trees help manage stormwater runoff by intercepting and storing rainwater and increasing infiltration.

Arguably, stream restoration can be included in this category. Taking many forms, from daylighting streams to bank stabilization and plantings, it aims to enhance the integrity of the stream's function, improve habitat and reduce erosion attributed to the volume and velocity stormwater runoff from impervious services.

Clockwise from the left: Donaldson Stream Restoration, source: chesapeakestormwater.net/wp-content/uploads/2012/08/donaldson-run-stream-restoration.jpg. Floodplain restoration, pre and post construction conditions, source: RK&K.

For more information

Overview of Green Infrastructure

The two resources listed below offer general information and anoverview of green infrastructure and stormwater manamgnet.

- Municipal Online Stormwater Training Center. https://mostcenter.org/

  The Municipal Online Stormwater Training Center (MOST) offers free, online education and training resources in the Chesapeake Bay. The courses cover a range of municipal stormwater issues, including financing, program development, asset management. The courses are tailored to specific audiences, such as local government staff, elected leaders, non-profits, and businesses. Each course is broken into short modules, with interactive quizzes, videos, presentations and insights from municipal managers of green infrastructure and stormwater more generally.

- US EPA. https://www.epa.gov/green-infrastructure/learn-about-green-infrastructure

  US EPA's website offers links to technical and educational information on green infrastructure. Some of the topics of interest include overviews of green infrastructure, practices and drivers for integrating GI, and local government approaches to compliance with federal regulatory programs (including MS4 permits, combined sewer overflows, and Total Maximum Daily Loads (TMDLs)).

Complementarity of Grey and Green Infrastructure

The Chesapeake Bay Stormwater Network offers a variety of resources to assist in identifying how GI as a retrofit can complement existing grey stormwater infrastructure, with a particular focus on maximizing infiltration with green before drainage to grey.

- http://chesapeakestormwater.net/bmp-resources/retrofits/

Guidance on Design and Use of Green Infrastructure

Each state offers a manual or guidance that describes grey and green practices for stormwater management. The following lists a few of these resources.

- DC Department of Energy and Environment. *Stormwater Management Guidebook*. https://doee.dc.gov/swguidebook
- Delaware Department of Natural Resources and Environmental Control. *Green Infrastructure Primer: A Delaware Guide to Using Natural Systems in Urban, Rural and Coastal Settings*. http://www.dnrec.delaware.gov/GI/Documents/Green%20Infrastructure/Green_Infra_Primer2016_FINAL%20web%20version.pdf
- New York City, Department of Environmental Protection. *Standard Designs and Guidelines for Green Infrastructure Practices*. http://www.nyc.gov/html/dep/pdf/green_infrastructure/bioswales-standard-designs.pdf
- Pennsylvania Department of Environmental Protection. *Pennsylvania Stormwater Best Management Practices Manual. Chapter 6. Structural BMPs*. http://www.elibrary.dep.state.pa.us/dsweb/Get/Version-48477/07_Chapter_6.pdf
- Philadelphia Water. *Green Stormwater Infrastructure Planning and Design Manual*. http://documents.philadelphiawater.org/gsi/GSI_Planning_and_Design_Manual.pdf
- US EPA. *Design and Implementation*. https://www.epa.gov/green-infrastructure/green-infrastructure-design-and-implementation
- US EPA. Performance of Green Infrastructure. https://www.epa.gov/green-infrastructure/performance-green-infrastructure

The resources highight that there is no shortage of GI design guidance. However, each state has unique differences that can materially impact design and construction. It is important that practicioners use GI approaches in a manner that meets the standards and specifications for compliance of relevant regulators.

Benefits of Green Infrastructure

Green infrastructure is recognized as an effective approach to delivering stormwater management *and* a wide range of additional benefits. This section organizes the benefits into four broad categories. They are:

- water quality and quantity
- air quality
- habitat and wildlife
- people and communities.

In addition to identifying the types of benefits found in each category, descriptions discuss metrics and monetary values attributed to each. The discussion is meant to be introductory, references for further reading and information is provided at the end of the section.

MEASUREMENT AND VALUATION OF BENEFITS

Assessing the impact and significance of benefits has two components – measurement and valuation. Measurement is the quantification of benefits with the aim of understanding the magnitude or impact a GI practice. Valuation involves the assignment of a monetary value to the units of measured benefits. Measurement and valuation combined provide a figure that allows costs and benefits to be assessed over the course of a GI’s operational life.

Water Quality and Quantity

Water quality and quantity often have the most direct relationship to *why* GI is installed and *how* GI is designed to perform. This relationship means that GI benefits are often measured with respect to its impact on an existing system of stormwater infrastructure.

Reducing Pollutants

In many cases, regulatory requirements related to water quality standards drive the design and installation of GI practices. Stormwater runoff from developed (and agricultural) landuses transport pollutants – such as nutrients, sediment, litter and oils – to waterways. GI practices help improve water quality by capturing and/or treating the runoff, thereby reducing pollutant loads delivered to streams, rivers, lakes, estuaries and other waterbodies.

As a driver of environmental protection, reduced pollutants is a primary indicator of the benefits of green infrastructure. In many instances, the benefit or positive impact of GI in reducing pollutants can be measured based how it changes the anticipated costs of regulatory compliance. For many older cities with combined storm and sanitary sewer systems (such as Philadelphia, PA, Lancaster, PA, Washington DC and Cleveland, OH), GI has offered a significantly cost-effective approach to addressing combined sewer overflows. For MS4 communities and other areas focused on sustainability, GI is a strategy that allows them to address water quality concerns driven by restoring watershed health.

Three commonly applied approaches to measuring and valuing reduced water pollutation are:

- avoided or deferred costs for water treatment
- avoided or deferred grey infrastructure investment
- household willingness to pay for watershed restoration.

WATER QUALITY AND IMPERVIOUS COVER

Green infrastructure can alleviate the impacts of impervious cover. The link between impervious cover and water quality is well established.

- Sensitive streams have watersheds that are below 10% impervious cover. These streams have good to excellent water quality and habitat.
- Impacted streams are found in watersheds with impervious cover between 10% and 25%. These streams have water quality and habitat impairments.
- Non-supporting streams are found in watersheds with over 25% impervious cover. The severity of water quality and habitat impairments is significant enough that they are not considered suitable for restoration.

Source: //www.landandwaterpartnership.org/documents/Summit2012/2I-Impervious-cover-fact-sheet.pdf

Avoided or deferred costs. Avoided or deferred costs can account for changes in operating costs or planned capital expenditures. These two benefits are closely related but enter municipal and utility budgeting practices differently. Avoided or deferred capital expenditures are planned infrastructure or asset expenditures reflecting the replacement or expansion of the storm sewer infrastructure, such as replacing pipes, pumps and culverts. Avoided or deferred costs for water treatment focuses on how GI impacts the costs of a stormwater program run by a municipality or stormwater utility. With avoided or deferred water treatment costs, the focus is on operating expenditures associated with maintenance activities or inputs such as chemicals to treat water or electricity for pumps. These operation and maintenance expenditure are ongoing and generally excluded from grant funding.

In both cases, these benefits account for how introducing or expanding GI practices affect an existing (grey) stormwater infrastructure system. The magnitude of the cost savings is measured in terms of how they change planned or anticipated costs and are likely to be direct benefits determined by the GI’s design specifications. As such, the size of this benefit is site specific and should not be based on the transfer of unit costs savings estimate (eg dollar per avoided gallon of water) from one municipality to another.

For example, avoided or deferred costs for grey infrastructure will be based on the difference between a grey and green BMP treating the same area or volume of stormwater runoff. A number of studies indicate the scale of this costs savings in the context of combined sewer systems. For example, CNT and American Rivers (2010) provides a general indication of the benefits of GI for avoided water treatment costs. It values avoided water treatment costs at $0.0000919 per gallon of water avoiding treatment. However, this estimate does not offer insight into how the scale or extent of GI practices impact MS4 programs. The CNT and American Rivers estimate reflects a combined rather than separate storm sewer system, which limits is application to other study sites.

Value of improved water quality. An alternative approach to measuring improved water quality uses general or public values rather than the difference in direct municipal or utility expenditures. This approach is best applied to valuing a programmatic approach to managing stormwater with green infrastructure practices, rather than making a project-by-project case for GI practices.

This benefit measure uses changes in indicators of ambient water quality, such as water clarity or pollutant concentrations, rather than areas or volume of stormwater captured and/or treated. Generally, two types of values have been applied to water quality improvements. They are household willingness to pay (WTP) or changes in residential property values. Household willingness to pay estimates often reflect values based on changes in water quality outcomes as they relate to pollutant concentrations, extent of riparian and/or stream/watershed restoration initiatives. For example, willingness to pay ranges from $14 to $28 per household per year for reductions in sedimentation (Braden and Johnston, 2004). WTP for river restoration to water quality standards referencing various human uses (ie, boatable, fishable, potable) can range from $85 to $378 per year per household (Braden and Johnston, 2004). While the transfer of values from these studies is challenging given the context and unique combinations of environment outcomes, they indicate that households value these improvements and have a general willingness to support programs delivering these ecological services.

Hedonic studies estimate values in terms of how the price of a good (in this case, residential properties) changes with varying characteristics. Most of the available studies focus on waterfront properties. However, a handful of studies provide estimates that can be applied to homes across a watershed. Depending upon the size of the study area and the extent to which GI can be modeled to show a measureable change in water quality, the benefits can be significant.

CNT and American Rivers (2010) reference values from a hedonic study conducted in the St. Mary's River Watershed (in the Chesapeake Bay). It finds that property values increase by:

- $1,086 for a one milligram per liter decrease of total suspended solids (TSS)
- $17,642 for a one milligram per liter decrease of dissolved inorganic nitrogen (DIN).

These estimates indicate that the value of water quality improvements can be significant, especially if applied to a large number of residential homes. The challenge however, is that the scale of the GI implementation needs to be sufficiently large enough to impact ambient water conditions in the Chesapeake Bay. In most cases, smaller MS4 communities will have a difficult time establishing the logical link and scale between GI designed to meet local stormwater treatment and material changes at in the Bay.

Flood Mitigation

GI practices mitigate flood risk. Urbanized areas are characterized by their intensity and breadth of impervious cover and compacted soils. These hardscape, man-made surfaces (eg, asphalt, rooftops) and compacted soils prevent the absorbtion of rainfall where it lands. GI practices reduce the amount of impervious surface and establish vegetation that can slow the flow and volume of stormwater runoff.

The benefits of flood mitigation can be valued one of three ways: avoided costs of clean up and/or repair, changes in flood insurance premiums, or impact on property values. Hedonic studies provide estimates of the benefits of flood mitigation in terms of its impact on the average price of a home. CNT and American Rivers (2010) recommend estimating the benefit of flood mitigation as 2 to 5% of average house price in the study area. This value applies to homes removed from a 100-year flood plain.

Water Supply

Rain barrel. City Hall, Edmonston, MD.

GI practices offer two pathways to benefiting water supply. The first is through rainwater harvesting and reuse. Although this practice does not mimic natural processes, it can assist in managing stormwater runoff. Water collected in rain barrels, cisterns and other structures can be used for outdoor irrigation and other non-potable uses. The second pathway is through groundwater recharge. Rainfall on permeable surfaces allows water to infiltrate into the ground, eventually recharging aquifers or joining subsurface flows that connect to surface water (CNT and American Rivers, 2010). This recharge is an important part of the water cycle.

The benefit of augmenting the water supply through green infrastructure is measured based on the volume (eg, gallons) of stormwater harvested or captured based on rainfall, the catchment area or affected surface area and the local retail water price. (See the earlier green roof example for how to calculate the volume of water captured.) CNT and American Rivers (2010) note that the volume of harvested water should also account for water loss due to evaporation, inefficient gutter systems and other factors. Their guidance suggests using a collection efficiency factor of 85% (that is, 15% of the captured water is not available for use).

Air Quality

Reducing Air Pollutants

Increased vegetation – and, in particular, trees – associated with GI practices serve as important 'filters,' removing air pollutants. Benefit studies focus on the link between trees and reducing atmospheric CO_2, particulate matter, nitrogen oxides, and volatile organic compounds. This filtering of air pollutants delivers a chain of benefits impacting human health and energy use.

Drawing on US Forest Service research, the estimates for valuing the abatement of air pollutant emissions are provided in the following table. On a per pound basis, the values range from less than one cent to just over $8. Most of these values reflect multiple benefits, including health benefits that occur both onsite and offsite. Their aggregation of multiple benefits increase the risk of double counting with other benefits.

Benefits of Air Pollutant Reductions – Annual Figures

Pollutant	Per Tree Uptake (lbs/tree)	Green Roof Uptake (lbs/ft^2)	Energy Use Change (lbs)	Value ($/lb)
NO_2	0.37	0.000477	61,983	$4.59
O_3	0.29	0.000920	37,220	$4.59
PM_{10}	0.33	0.000133	39,628	$8.31
SO_2	0.40	0.000406	68,376	$3.48

Source: US EPA, 2014.

Health Effects

GI practices through improved air quality can reduce the risk of health impacts ranging from asthma to premature mortality. In turn, avoidance of adverse health outcomes can contribute to increased productivity and fewer hospital admissions. The value of morbidity and mortality impacts are included in the estimates cited for each air pollutant in the previous section.

Heat Island Mitigation

"Heat island" effect is associated with urban environments, where buildings and pavement surfaces absorb solar radiation, becoming very hot and warming the surrounding air to temperatures that are several degrees warmer than the countryside (Akbari, 2005; Gill et al, 2007). GI introduces vegetation that provides shading and evaporative cooling that can mitigate the heat island effect. The resulting lower ambient temperatures lead to lower energy use for cooling and reduced hospital visits and other heat-stress related health effects.

Generally, a conservative approach would involve measuring but not monetizing benefits of mitigating the heat island effect. As a general indication, a 10% increase in vegetation can lead to 1°C reduction in day time surface temperature.

Many benefit studies also include second-order effects as consequences of the lower energy use. Second-order benefits include reductions in GHG and other air pollution associated with lower energy demand (gas and electricity) for cooling.

Habitat and Wildlife

US EPA identifies GI practices as supporting habitat improvement and/or connectivity, particularly in urban settings. The habitat improvement emerges through vegetation that support insects, birds, and other wildlife and as a direct result of better water quality attributed to reduced erosion and sedimentation. The benefits of habitat connectivity typically arise from larger-scale green infrastructure. GI links parks and urban forests, allowing wildlife to move among habitats.

Philadelphia Water Department in its assessment of green infrastructure valued water quality and habitat enhancements between $10 and $15 per household per year (Stratus Consulting, 2009). The study applied this value to households affected by restored stream miles.

Empirical estimates of the value of benefits in this category are closely related to those for water quality improvements. In many instances, valuation studies will use water quality indicators that include a habitat or wildlife component. As a result, adding the benefits of this category to that of water quality benefits should be done cautiously to avoid potential double counting.

People and Communities

This category captures the suite of benefits that impact the social dimensions of neighborhoods or regions. Commonly identified community benefits include recreation, health benefits, increased property values, social cohesion and jobs. Valuation of these benefits often include aspects that cross categories, making it difficult to avoid double counting (eg, recreation and health benefits). As a result, emphasis should be placed on quantifying rather than monetizing these benefits.

Recreation

GI is often located in open spaces and used to add amenity value to passive and active recreational activities, such as walking and habitat viewing. It can help transform an underutilized or hardscape space to be an area for public use and recreation.

A rich body of literature exists to value recreational benefits. However, only a limited number of studies consider urban recreation. The significance of this benefit category will be highly site dependent, reflecting not only the existing amenities but also how green infrastructure interacts to enhance or expand recreational use.

Health Benefits

Increased presence of green infrastructure contributes to improved mental and physical health outcomes. GI enhances opportunities for physical activity that can lead to reduced rates of obesity, heart disease and other chronic diseases. This link to health outcomes is still being developed. Empirical research continues to explore and characterize the relationship between urban green space and physical activity.

Property Values

A strong body of literature supports the positive impact of GI on property values. GI practices add value to property through improved aesthetics, proximity to active or passive recreational opportunities, and other local amenities. Braden and Johnston (2004) in synthesizing the economic values of stormwater management note that aesthetics tend to be integrated or already embedded in empirical estimates of the value of water quality improvements found in WTP and hedonic studies.

Social Cohesion

Green spaces promote social interaction and local attachment by drawing people out to a shared space where they have an opportunity to interact with each other. It can strengthen the social capital for a neighborhood, leading to lower crime rates, improved sense of wellbeing, and greater feelings of safety for residents. Research shows that a 10% increase in tree cover is associated with a 12% reduction in crime.

Jobs

As GI becomes more integrated in planning and approaches to development, it is emerging as a new sector and source of jobs. GI design, construction, and maintenance requires a wide range of skills and services, including engineers, planners, architects, ecologists, landscapers and construction workers. Training and certification programs are also emerging in support of this growing industry.

For more information

US EPA offers a webpage and links that elaborate on each category of benefits. This information can be found at https://www.epa.gov/green-infrastructure/benefits-green-infrastructure.

The sources below provide examples and guidance for understanding how GI supports benefical outcomes across the triple bottom line. References provided in the next section, *Framing Benefits*, will provide examples of how studies have quantified and monetized benefits in both MS4 and combined sewer contexts.

- *Benefits of green infrastructure*. https://www.forestry.gov.uk/pdf/urgp_benefits_of_green_infrastructure.pdf/$file/urgp_benefits_of_green_infrastructure.pdf
- *Exploring the Green Infrastructure Workforce.* http://www.jff.org/sites/default/files/publications/materials/NatureWORKS-Issue-Brief-032317_v3.pdf
- *Green Cities: Good Health*. depts.washington.edu/hhwb/
- *Health benefits of urban vegetation and green space: Research roundup*. https://journalistsresource.org/studies/environment/cities/health-benefits-urban-green-space-research-roundup

Framing Benefits

The two previous sections review GI practices and benefits. This section focuses on guidance for connecting the GI benefits to local communities.

It follows a four-step process:

- define the goal(s) of the analysis by setting a clear objective for assessing benefits
- distinguish between direct benefits and "co-benefits"
- inventory and assess the most meaningful benefits
- tailor the characterization of benefits assessment to the purpose.

Setting the Objective

The rationale for assessing benefits can be multi-pronged. For many local governments, the concept of green infrastructure emerges in response to one or more the following drivers:

- regulatory compliance
- climate resiliency
- sustainability initiatives
- community partnerships.

This document focuses on GI installed in response to stormwater regulations and sets out how to holistically evaluate its benefits. The approach begins with clearly identifying the goal(s) of the assessment. GI benefits emerge from a complex system of interactions. Without setting a clear goal(s) and objective(s) to assessing the benefits of

GI, it is difficult to know how to allocate limited time and resources to data gathering and analysis.

QUESTIONS TO HELP SET GI BENEFIT ASSESSMENT GOAL(S)

The following questions help in trying to establish the assessment's goal(s).

- Why assess benefits?

  Identifying benefits is not always necessary – especially if the project or program has strong support or is already well-established. However, as the adequacy or acceptability is more strongly questioned, the need for understanding and assessing benefits is likely to increase.

- Who is the primary consumer or audience for the benefits information?

  In many cases, the information needed to influence the decision-maker will differ from what is needed to inform the general public. The differences will impact the metrics, precision and robustness of information supporting benefits of using GI approaches.

- What does the benefits assessment need to support, eg, cost recovery/fee setting, prioritization of options, planning?

  In the context of cost recovery or setting fees emphasis will likely focus on the efficiency and effectiveness of approaches to managing stormwater to meet regulatory compliance or service requirements. For prioritization and planning settings, the broader spectrum of benefits across grey and green stormwater practices will likely play an important role. However, depending upon the framework, benefits may be characterized in terms of directional changes, ordinal scale or monetary figures.

- Are the benefits being used to support trends and annual reporting or to evaluate a particular project?

  Annual and trend reporting focuses on actual performance. The reporting will dictate the measurement and metrics with a focus on consistency to allow aggregation over time or comparison across years. Evaluating GI practices may require identifying how to best integrate its benefits into an existing reporting framework.

Distinguish between Direct Benefits and Co-Benefits

Holistically evaluating the benefits of green infrastructure involves distinguishing between direct benefits and co-benefits. Direct benefits respond to the regulatory or utility service driver. They often define the design specifications for the performance of the GI practice. For example, GI practices designed and installed for the purposes of MS4 compliance deliver direct benefits in the form of pollutant reductions. In the context of combined sanitary and storm sewer systems, GI reduces the volume of stormwater entering into the system and requiring treatment. The direct benefits are observed in operational costs savings, deferred maintenance activity, and avoided/deferred capital expenditures. These direct effects are the product of design and performance specifications. They are integral to the goals for implementing GI and can be measured.

Most of the benefits attributed to GI are co-benefits. Co-benefits is “shorthand” for coincidental benefits. They are additional benefits – or positive impacts – that occur *in addition to* a GI practice meeting its performance specifications. In most cases, these positive impacts are *external* to a stormwater network or infrastructure system. They impact the people and places in and around the GI site.

Example for distinguishing between direct benefits and co-benefits

GI can be a strategy that emerges from a variety of different municipal departments, including public works, roads and transportation, parking, economic development, public health and parks and recreation. For each department, the way in which GI supports or complements core activities will vary. For example, GI may provide a way of addressing nuisance flooding for a local resident caused by poor road drainage. Depend on the design and how implementation is coordinated with other road work, GI may provide a cost-effective option. The challenge is understanding how GI can fit into the suite of tools and options for each municipal department.

The following three scenarios illustrate how the goals of installing GI defines direct benefits and co-benefits. Green infrastructure can play an important role for local governments through several pathways. They include stormwater management and compliance, beautification and livability, and sustainability. In each scenario, the installed GI practice is the same – green streets – and performance specifications would be similar. Varying goals defines the objective for using GI and how benefits may be measured for each scenario.

Scenario 1. Goal of MS4 Permit Compliance. A local government must implement stormwater management practices to reduce sediment loads that are part of its MS4 obligation. It installs a series of green streets as part of best management practices to meet its permit requirements (ie, goal). The direct benefit is the sediment removal credited to the permit as a result of the practice's installation. However, the green streets also enhance the aesthetics of the streetscape and result in higher pedestrian use and increased property values. These additional benefits or aesthetics, higher use and improved property values are co-benefits.

Scenario 2. Goal of Community Revitalization. In the second scenario, the local government installs green streets as part of its neighborhood revitalization initiative (ie, goal). It adopts green street practices to enhance the aesthetics and lift property values. The green streets deliver additional benefits of treating stormwater runoff (which may or may not be a permit requirement) and increasing pedestrian use. In this scenario, the green streets have a performance target that is measured by its ability to increase property values. The increased property prices are a direct benefit rather than a co-benefit. The higher pedestrian use and pollutant removal from stormwater runoff are co-benefits.

Scenario 3. Climate Resiliency. The third scenario involves the local government installing green streets as part of its climate resiliency initiative. It uses green streets to enhance the existing storm sewer system in anticipation of changes in future precipitation patterns. The direct benefit is reduced frequency of nuisance flooding which may be measured through the change in the frequency of emergency response and public works responses. As in scenario 2, added benefits (or co-benefits) are stormwater pollutant removal, enhanced aesthetics, higher pedestrian use and increased property values.

The examples illustrate how setting goals defines direct benefits that are the measure of how well a GI project performs. In each scenario, a common set of benefits emerge: stormwater runoff treatment, improved aesthetics, and increased property values. Despite a common GI practice, the direct benefit and how its measured changes significantly based on the driver for installing GI. In the first scenario, the direct benefit is pollution reduction which can be measured in terms of its relative cost-effectiveness. In the second scenario, the key benefit is measures is the change in property prices.

The third scenario focuses on impacts to emergency response and public work call-outs. The pathways, data needs, measures and values are unique to each scenario (ie, goal).

As a general practice, assessment efforts should begin with prioritizing direct benefits over co-benefits. Resources should be devoted to first assessing how direct benefits can be measured and if the measurement is possible (given data availability and quality). Co-benefits can then supplement the analysis, but the level of effort and precision of measurement should be tailored to resource constraints and reflect their importance to stakeholders.

Framework for Inventorying Co-Benefits

The triple bottom line (TBL) offers a useful framework for identifying the full range of co-benefits attributed to GI implementation. The triple bottom line also offers a way to recognize the value or benefits that are broader than the financial bottom line measured in a municipal budget.

TBL establishes three broad areas of impacts – environmental, social and economic.

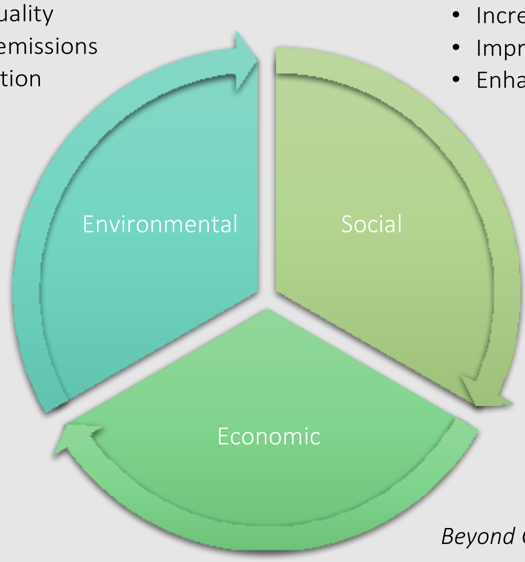
- The environmental bottom line considers environmental outcomes beyond pollutant removal (for stormwater compliance). Among the benefits identified in the previous chapter, co-benefits for this category include those discussed in air quality and habitat and wildlife, such as air pollutant removal, heat island mitigation and habitat connectivity.
- The social bottom line captures benefits to communities, such as social cohesion and improved mental and physical wellbeing.
- The economic bottom line considers how GI stimulates economic activity and job creation. To capture only the co-benefits, the economic bottom line focuses on impact *outside* of the municipal budget or stormwater utility's operations. For example, cost savings between traditional and green approaches to stormwater management should not be included in the TBL assessment of co-benefits. However, reduced electricity usage for heating and cooling due to GI practices mitigating a heat island effect should be included.

TRIPLE BOTTOM LINE AND CO-BENEFITS

Beyond water quality…

- Improved air quality
- Reduced GHG emissions
- Habitat restoration

- Recreational opportunities
- Reductions in crime
- Increased beautification
- Improved health & wellbeing
- Enhanced social cohesion



Beyond Cost Savings…

- Job creation
- Redevelopment
- Increased property values

The figure above identifies some of the GI co-benefits associated with each component of the TBL. The framework along with the benefits identified in the previous chapter provide a core foundation of identifying the full spectrum of GI co-benefits. However not all co-benefits are likely to be relevant or significant. The list of co-benefits should be screened and prioritized to reflect the ones that are likely to be relevant and significant to the community.

As a first pass, each co-benefit should be linked to information that helps gauge its significance. Useful information in this step are:

- describing the coverage of the impact in terms of populations and geographic coverage (ie, the number of individuals)
- determining how many factors or causal links exist before the co-benefit is realized (ie, the scale of realized benefits).

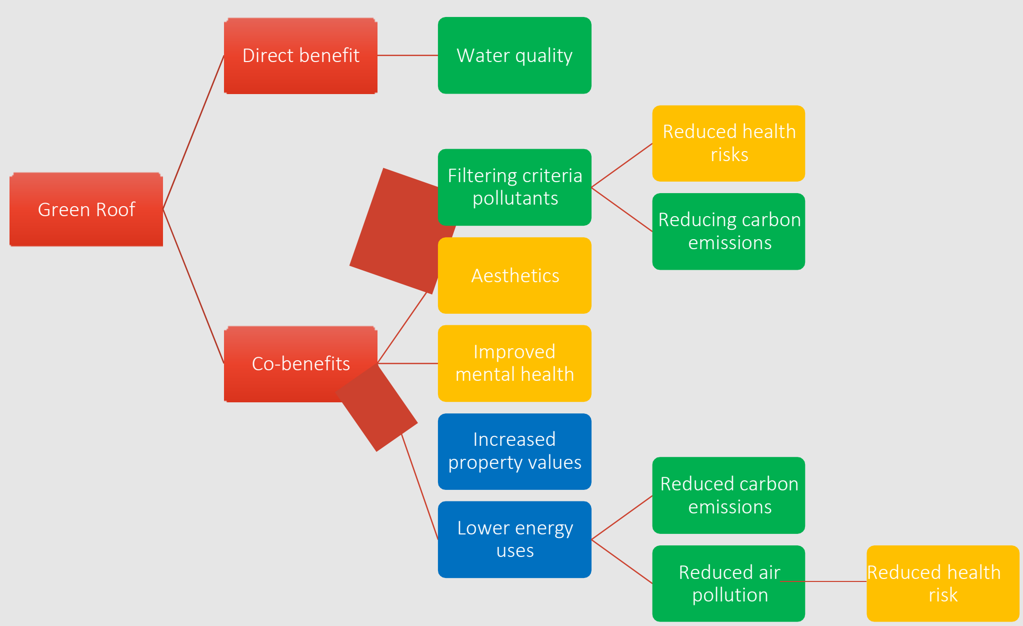
The MS4 program generally requires stormwater management in urbanized areas. The density and number of people or households likely to be impacted by the GI practice offers a meaningful indicator of its importance. This type of information tends to be readily available based on municipal mapping of storm sewersheds and census data. Land use and zoning information can also act as approximations for the potential magnitude of municipal residents impacted. For example, a green roof can add amenity value through improved aesthetics and reduce energy use for heating and cooling. However, if located in a low density area or in an area with a mix of industrial and commercial warehouses, the aesthetic benefits are likely to be low, while the energy savings may be significant. In contrast, a green roof located in a dense residential or commercial area will likely have aesthetic and energy use co-benefits that are considerable because of its high visibility and/or building occupancy.

The second screening approach focuses on the certainty of a co-benefit being realized. Returning to the green roof example, the first round of air quality impacts arises from the green roof's vegetative filtration of the air. This filtration reduces the risk of adverse health effects like asthma. In addition, the green roof acts as insulation that moderates building temperature and reduces energy use for heating and cooling. The reduced demand for energy leads to lower air pollutant emissions from electricity generators. In turn, reduced electricity generation leads to less emission of particulate matter, which contributes to lower risks of adverse health effects like asthma.

In this scenario, co-benefits have two rounds of public health impacts and demonstrates how a longer the chain of connecting links raises uncertainty. The figure below illustrates the connections for this example. It demonstrates how one set of reduced health benefits are more directly related to the green roof installation than the other. Realizing public health benefits from lower energy use requires responses in the energy generation market that is not directly or strongly impacted by the GI practice. It also calls into question where the second round of health benefits occur (due to changes in energy consumption), that is whether they are in the municipality/study area. It points to the potential importance of evaluating populations in the immediate surroundings of the GI practice, as well as raises questions of whether public health benefits flowing from the energy savings should be pursued. Direct transfer of pollutant reductions and values (such as the ones provided in the table, Benefits of Air Pollutant Reductions – Annual Figures) masks these distributional and certainty issues.

The figure below also color codes the co-benefits to represent the triple bottom line. Environmental impacts are green. Social impacts are yellow, and economic impacts are blue. The color coding illustrates how impacts across the three bottom lines are intertwined. The complexity of accounting for all the co-benefits and the multiple pathways for their emergence increases challenges in measurement and avoiding double counting.

CAUSAL CHAIN OF CO-BENEFITS: EXAMPLE USING GREEN ROOFS



Notes: The color-coded boxes assist in overlaying a TBL framework. Green boxes indicate environmental impacts. Yellow boxes indicate social impacts, and blue boxes indicate economic impacts.

Ways to Use Co-benefits in a Stormwater Program

Having gone through the exercise of identifying which beneficial impacts of GI are direct and which are co-benefits, and then conducting a high-level screening of the co-benefits inventory, a natural next step is to consider how to quantify and/or monetize benefits. However, depending upon the purpose of the assessment, (ie, grant application, public meeting, council approval), benefits may only need to be qualitatively described rather than quantified or monetized.

The following identifies five ways that holistically assessing GI benefits in a stormwater program can assist.

- Cost-effectively achieving regulatory compliance. In this context, direct benefits and their cost-effectiveness or ability to deliver value for money generally drives the decision process. Municipalities and utilities have to balance multiple portfolios and/or service objectives. Co-benefits serve as valuable information to selecting or prioritizing among multiple stormwater BMPs that all meet minimum design/performance specifications. The co-benefits often need to be characterized (assessed on a relative scale or reported in terms of directional changes relative to a baseline), rather than quantified or monetized.
- Community engagement. GI practices represent diffuse practices of varying scales. They often rely on engaged community organizations and citizens to assist in the identification of candidate sites or their care and monitoring post-installation. The identification and characterization of how, where and who are impacted by the co-benefits of GI can assist in two ways. Articulation of meaningful co-benefits can promote the ownership and care of these sites, or it can raise awareness and acceptability of stormwater expenditures.
- Addressing underserviced communities. Many of the social and economic co-benefits are elements of a community's social capital and cohesions. When looking to site stormwater BMPs in traditionally underserved communities, these co-benefits can provide much needed added value to the community's assets. It also can service as a platform for dialogue and community engagement.
- Motivating collaboration. The TBL framework looks across private, public and nonprofit sectors to identify where co-benefits emerge. Understanding the strength of the co-benefits is a platform for engaging new partners or initiating new collaboration with existing partners.

- Pursuing grant funding. Articulation of co-benefits in terms of their scale and significance can often play an important role in making a compelling case for competitive grant funding.

In these approaches, the co-benefits inform decisions and motivate acceptance based on *where and who benefits* rather than their monetary value. Put another way, the benefits assessment focuses on the distributional attributes of the co-benefits and the certainty of the benefits materializing rather than assigning monetary valuation. The table on the next page provides guidance for how direct benefits and co-benefits can assist and when it can be helpful to characterize, quantify or monetize them.

This approach responds to local governments facing a compliance responsibility for managing stormwater. In this context, investment in stormwater management is a given. The decision is around how to best meet those obligations and justify the associated expenditures. The case studies, found in the appendix, illustrate the role of benefits and co-benefits played in the implementation of green infrastructure projects.

WHEN TO MONETIZE BENEFITS

The level of effort, precision and metrics for conveying GI benefits should be tailored to the audience. Below provides guidance on the role of direct benefits and co-benefits. It identifies where the ability to assign monetary valuation is likely to be necessary, as opposed to characterizing or measuring the types and scale of co-benefits.

Context	Direct Benefits	Co-Benefits	Comments
Regulatory Compliance	Monetary measures essential.	Ancillary. Measured not monetized.	• Focus on establishing least-cost or most effective approach. • Co-benefits needed when all else equal (ie, in terms of feasibility, timing and cost).
Community Engagement		Essential. Measured not monetized.	• Focus on believeability and tangible nature of co-benefits.
Underserved Communities	Monetary measures helpful.	Essential. Measured not monetized.	• Monetary measures helpful in making a case for most effective given the investment. • Focus on believeability and the tangible nature of co-benefits – articulate *why* relationship between investment and benefits emerge.
Motivating Collaboration		Essential. Measured and/ or monetized.	• Metrics – measurement or valuation – depends interests of the collaborating partner(s).
Grant Funding	Monetary measures helpful.	Helpful. Characterized at minimum.	• Monetary measures may be helpful in justifying funding request. • Increased percision of co-benefits can be useful.

For more information

US EPA offers a webpage and links to cost-benefit analyses of GI. This information can be found at https://www.epa.gov/green-infrastructure/green-infrastructure-cost-benefit-resources.

Other useful references include:

- *The Value of Green Infrastructure. A Guide to Recognizing Its Economic, Environmental and Social Benefits.* www.cnt.org/sites/default/files/publications/CNT_Values-of-Green-Infrastructure.pdf

  This document provides guidance on how to quantify and monetize a range of benefits attributed to green infrastructure. The document does not differentiate between direct benefits and co-benefits.

- *The Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds. Final Report.* https://www.epa.gov/green-infrastructure/triple-bottom-line-assessment

  This report illustrates how large municipal water departments with a consent decree for addressing combined sewer overflows (CSO) approach measuring and valuing avoided costs and co-benefits.

- Peck, Steven and Vincent Javet. 2015. *Green Infrastructure Design Charrette. Making the Business Case for Green Infrastructure Investment in Your Community.* Final Report. January.

  This report provides a cos-benefits matrix that provides values that can be applied based on the size of the GI practices. It also distinguishes between private and public benefits.

- *Green Values National Stormwater Management Calculator*. http://greenvalues.cnt.org/national/calculator.php

  The on-line calculator and its accompanying documentation supports valuation of benefits.

Summary

This document is intended for smaller local governments with stormwater programs that largely respond to regulatory compliance with municipal separate storm sewer system (MS4) obligations (eg, Phase 2 communities). It outlines an approach to holistically evaluate the benefits of green infrastructure. The guidance places emphasis on first understanding the purpose and scope to bound the analysis and determine which beneficial outcomes are most relevant and how they need to be measured.

While discussion of grey and green infrastructure often presents the two approaches as an "either-or" decision, the practical reality is that they are complementary. The decision for many municipalities is not between grey or green approaches. Instead, it is about *what is the best approach* to managing stormwater. Grey stormwater infrastructure is a vital part of urban and developed areas. Municipalities face the choice of how to improve the capacity of functioning of this "grandfathered," engineered system. Green infrastructure provides a potentially effective and integrative approach to managing and/or augmenting existing municipal assets, be it stormwater, parks, buildings or roads. Its potential to offer direct and ancillary benefits depends upon how GI interacts with existing stormwater practices and the built environment around it.

Identify the purpose for assessing benefits.

Green infrastructure delivers a wide range of positive outcomes that benefit the environment, communities and local economies. Evaluating the full spectrum and reach of GI benefits is complex and challenging. Considering the full range of GI benefits is important to making difficult decisions about how to allocate limited municipal resources or conveying the effectiveness of spending decisions. However, smaller local governments are likely to have limited staff, capacity or expertise.

This document sets out an approach that begins with clearly identifying the purpose of the assessment. This step sets boundaries to the analysis and directs efforts to the area(s) most relevant to stakeholders.

Not all benefits are the same.

While our understanding of the full set of benefits arising from GI is not likely to change over time, but the certainty and accuracy of characterizing them will.

With the purpose and boundary of the benefits assessment determined, the next step is to understand their relative importance in terms of impact and value. Not all benefits have the same significance, scale or coverage. A first step in evaluating benefits is to identify which benefits are direct and which are co-benefits. As illustrated in the previous section, the full set of benefits for GI do not vary much (eg, stormwater runoff treatment, improved aesthetics, increased property values). However, the direct benefit changes based on the driver for installing GI. Clearly articulating the direct benefit(s) often define the benchmark for evaluating how well a GI project meets its objective.

As a matter of practicality, resources and effort should be devoted to first assessing how direct benefits can be measured and measuring direct benefits in a credible manner. Co-benefits can then supplement the analysis, but the level of effort and precision of measurement should be tailored to resource constraints and reflect their importance to stakeholders.

A TBL framework can guide holistically evaluating the benefits of GI.

Once the direct benefit is identified, the assessment should focus on developing an inventory of co-benefits and then prioritizing them in terms of importance.

A TBL framework offers one way to systematically consider the full spectrum of potential co-benefits that occur outside of the stormwater asset or infrastructure system. Rank-ordering the inventory is an important step to assuring the analysis focuses on meaningful outcomes. An initial screen can consider either, or both, of the following dimensions:

- describing the coverage of the impact in terms of populations and geographic coverage
- determining how many factors the co-benefit depends upon before it can be realized.

Let the role of direct benefits and co-benefits guide the need to monetize benefits.

Information about co-benefits can be used to support the decision-making process and implementation of a stormwater program in five distinct ways:

- cost-effectively achieving regulatory compliance
- community engagement
- addressing underserviced communities
- motivating collaboration
- pursuing grant funding.

A valuation or benefit-cost analysis is not always needed. Depending upon the use, co-benefits may only need to be characterized or quantified. In these approaches, the co-benefits inform decisions and motivate acceptance based on *where and who benefits* rather than their monetary value. Put another way, the benefits assessment focuses on the distributional attributes of the co-benefits and the certainty of the benefits materializing rather than assigning monetary valuation.

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CASE STUDIES

Case Study #1: Maryland MS4 Communities

About Local Government. With the exception of the City of Baltimore, Maryland has 23 counties and 156 municipalities. While municipalities or local governments vary significantly in scale, such as population and area, they tend to be small. Nearly 40% have populations less than 1,000; only nine have populations greater than 25,000.[1] The process of developing these case studies, five local governments in Maryland were engaged. Three of the local governments are among the largest (with populations greater than 50,000), while the other two are significantly smaller, with populations between 5,000 and 15,000.

Annual Spending on Stormwater. The capacity and ability to finance stormwater – and green infrastructure (GI), more specifically – is materially different at the county level versus the local government level. With a longer history and more extensive requirements as Phase 1 MS4 communities, county governments in Maryland have larger budgets, deeper technical capacity, and greater resources and expertise the delivery and coordination of diffuse stormwater infrastructure. While reported estimates on total municipal expenditures specific to stormwater are not available, comparing total government expenditures and public works budgets is a helpful proxy. County government expenditures in Maryland totaled $28.5 billion in 2014. In contrast, total local government expenditures summed to $1.36 billion.[2] This equates to county expenditures being roughly 21 times larger than that of local government.

Even accounting for how local governments and county governments have different responsibilities and service delivery, county government spending is substantially greater. For local government, public works (including roads, sewer, waste and water) have the largest share of expenditures (upwards of 40%).[3] In contrast, public works is represents around 11% of total county spending; yet, county government still spends about 5.5 times more on these needs than local government.

Representatives within the public works department are often the local government point of contact for stormwater and green infrastructure. Public works budgets averaged $3.7 million, of which a portion will typically address the operation and maintenance of stormwater facilities. Capital improvement plan (CIP) will supplement stormwater programs, providing funding for retrofits and new BMPs. Although more common at the county level, some local governments will have stormwater fees or revenue from special taxing districts that provide a source of revenue for stormwater management. In these circumstances, the local government may have a dedicated stormwater unit and/or enterprise fund in their budget.

[1] Maryland Department of Legislative Services (2017). *Overview of Maryland Local Governments: Finances and Demographic Information*. Accessed 10/9/17, http://mgaleg.maryland.gov/Pubs/BudgetFiscal/2017-local-government-finances-demographics.pdf.

[2] *Ibid.*

[3] *Ibid*.

Approach to Stormwater Management. In Maryland, Phase 2 MS4 communities have traditionally developed approaches to managing stormwater based on six minimum control measures (MCMs):

- Public education and outreach
- Public participation/involvement
- Illicit discharge detection and elimination
- Construction site runoff control
- Post-construction runoff control
- Pollution prevention/good housekeeping.

These MCMs do not require the Phase 2 communities to actively restore existing impervious surface with public monies in order to comply with MS4 obligations. Instead, Phase 2 municipalities need to manage new development and redevelopment by ensuring local ordinances address post-construction runoff. This means that for many of the Phase 2 communities green infrastructure or stormwater BMPs have been delivered by developers or through grants in partnership with nonprofits. In reviewing and permitting the installation of onsite practices, many capitalize on their ordinances to push developers to use green practices based on environmental site design (ESD) to the maximum extent practicable (MEP). The result has been the private sector delivering small scale, site-specific GI, such as green roofs and planter boxes. For Phase 2 communities experiencing strong economic growth (ie, redevelopment), this approach has been highly effective in "greening" their city.

However, Phase 2 MS4 municipalities know new requirements are coming. The new MS4 permit, expected to take effect in 2018, expands municipal requirements. MS4 communities will have to retrofit existing development to address 20% of untreated impervious acres. They will no longer be able to solely rely on private developers to deliver GI and stormwater BMPs more generally. Instead, they will have to spend public dollars on these practices. Faced with this new obligation, they will need to find new revenue streams and identify opportunities that balance meeting budget constraints, regulatory requirements and multiple – and often times competing – community expectations.

Prioritizing Stormwater BMPs and the Role of GI. The MS4 communities interviewed reported undertaking steps to inventory and identify potential projects that can help meet the anticipated changes in their MS4 permits. They tended to describe similar processes for identifying and vetting opportunities to address stormwater. They all agreed that green infrastructure is ideal, and none expressed doubt over the multiplicity of co-benefits that green infrastructure can deliver.

However, they did the view the current narrative around green infrastructure as potentially problematic for two reasons. First, they expressed that the decision about how to address stormwater obligations is not about whether to implement grey or green infrastructure. They felt this dichotomy was too simplistic. The challenge, they found, was in how to identify and select not only the most promising sites but also the practices that best work with the site's conditions and surrounding residents' needs. Most projects will involve several BMPs, and selecting the right mix for the site will be a reflection of:

- site feasibility (eg, soils, access)
- community acceptance (and willingness to make tradeoffs)
- maintenance capacity/requirements
- budget constraints.

These factors generally create “hybrid” solutions using both green and grey stormwater BMPs, such as retrofitting a basin and coupling it with a constructed wetland or plantings. Rather than developing tools to evaluate grey versus green options, the MS4 communities identified a need for assistance in how to evaluate and prioritize based on multiple criteria that reflects the local conditions, aspirations and needs. The larger Phase 2 communities have already invested in hiring consultants to not only inventory potential projects, but develop prioritization that reflected multi-criteria analysis. Co-benefits, not just costs, were integrated in these decision tools.

Second, the proposed change to Phase 2 MS4 permits places emphasis on stormwater treatment. Current guidance on green infrastructure can be misunderstood to suggest that treatment impacts should be downplayed in favor of co-benefits. With the new permit requirements and expected expenditures, public works and stormwater managers are focused on making the importance of stormwater management understood and accepted by their council, mayor and citizens. They shared that the need information that demonstrates how proposed BMPs will work effectively and operate as expected by the community. The grey or green distinction is less of a factor. The focus will be on the efficiency and effectiveness of BMPs in treating stormwater. Further cost savings are less insightful where the municipality has limited experience or data to benchmark the relative cost-efficiency of one approach versus another. To date, the evidence around the cost effectiveness/ cost savings delivered by green infrastructure is typically in a combined sewer context, which the MS4 communities viewed as less relevant to the MS4 setting.

Framing Benefits. The importance of community considerations extends beyond the prioritization process. The interviewed local governments emphasized the importance of integrating community preferences in design decisions and described needing to articulate the tradeoffs between design decisions and co-benefits. The community understanding these tradeoffs can drive a project’s success and its ability to go beyond stormwater compliance in delivering amenity and recreational outcomes.

This perspective shifts the focus to how co-benefits are framed. Characterization of co-benefits needs to demonstrate how they can reflect community considerations and the engagement process. Among the co-benefits identified in this document, aesthetics and recreation are significant decision drivers. The MS4 communities expressed that these co-benefits do not need to be quantified or monetized, but rather that information is needed to convey when the co-benefits will materialize and offer assurances about co-benefit being delivered and maintained.

Case Study #2: Bowie, Maryland

About the Municipality. Bowie, Maryland is an MS4 Phase II community located in Prince George's County, south of Baltimore, between Washington, DC and Annapolis. Its municipal area is approximately 18.5 square miles and hosts a population of 58,400. The City is mostly built out, but contains around 1,100 acres of parks and open space.

Annual Spending on Stormwater. For fiscal year 2017, Bowie has budgeted approximately $1.7 million for stormwater management including about $450,000 for maintenance and an additional $820,000 for stormwater retrofits in its Capital Improvement Program. The City does not have a stormwater fee. As a result, funding for stormwater comes primarily through the City's General Fund and special taxing districts which addresses regional pond maintenance.

Approach to Stormwater Management. Bowie first received its NPDES permit in 2003. Unlike other local governments in the County, the City is not a co-permittee on the County's Phase I permit. Bowie's regulated area spans the entire municipality. Its current permit requires the City to undertake six MCMs, including addressing stormwater in new development, redevelopment or infill based on environmental site design (ESD) to the maximum extent possible (MEP).

Redevelopment rather than infill or new development characterizes the landuse changes for the City. This redevelopment has served as a catalyst for private development to assume the costs and responsibility of stormwater retrofits that reflect a mix of traditional and green practices.

Around 40% of Bowie was developed in the 1960's and 1970's. These older sections are Levitt-style developments. Reflecting practices of that time, these areas were not designed with stormwater treatment, nor were existing stormwater pipes mapped. The City has focused on retrofitting some of these areas, installing large retention facilities and improving existing ponds. These approaches offer opportunities to not only capture larger volumes of water, but also cost-effectively treat stormwater.

The City differentiates these larger-scale practices from low impact design (LID) or green infrastructure (GI)approaches. Regional ponds and retention facilities are characterized as hybrid approaches that integrate stormwater capture and treatment (via filtration) rather than direct collection and conveyance. In contrast LID and/or GI are viewed as smaller, more diffuse practices that place emphasis infiltration for stormwater treatment. Their smaller scale presents greater challenges in terms of management and maintenance.

Prioritizing Stormwater BMPs. In 2013, Bowie engaged in a GIS exercise that inventoried all of its stormwater management practices. It conducted this exercise in anticipation of Maryland's new Phase II MS4 general permit (anticipated to take effect in 2018). This new permit will require communities to expand stormwater management obligations and retrofit existing development to address 20% of the untreated impervious surface.

The City has limited pipe mapping, but estimates that is has around 3,300 street inlets. In addition, it has more than 300 stormwater BMPs that are either privately- or publically-owned and managed.

After the inventory, the City had a retrofit analysis done, and 45 sites were assessed – 34 stormwater retrofit and 11 stream restoration projects. These sites were typically larger in scale. The average drainage area was 52 acres with an average of 19 impervious acres. (All but two sites treated over one acre of impervious.) Reflecting this scale, the majority of the BMP opportunities involved bioretention, retrofitting ponds, stream restoration and a few green infrastructure demonstration projects.

Based on guidance from the City, the consultant that completed the retrofit analysis ranked the 45 sites. With a focus on meeting (future) regulatory compliance. Preliminary ranking was not based purely on total cost (both construction and maintenance); it also considered feasibility, need, and efficiency. To address feasibility, preference was given to publically owned sites. To indicate need, the ranking gave preference to sites that, while not publically owned, were characterized by an absence of preexisting stormwater treatment. Lastly efficiency was taken into account by two measures: cost per impervious acre treated and pounds of nitrogen removed per acre treated. Amenity (aesthetics) and community buy-in were also important factors but these did not drive the selection process.

The City's stormwater workgroup then reviewed the ranked projects and identified 12 priority retrofit opportunities based on local knowledge about community receptiveness, history of the site and local conditions. The prioritization resulted in larger-scale, hybrid practices that incorporate elements of green infrastructure and engineered solutions. For example, retrofitting ponds involved deepening ponds to increase capture capacity and plantings to support stormwater filtration and community appeal. Stream restoration requires engineered solutions that enhance the overall ecological functioning of a natural asset.

The priority projects were not necessarily the largest or most cost-effective ones. Instead, selected sites tended to balance scale and cost-effectiveness along with the potential demonstration value of LID retrofits. The priority sites averaged 13-acre drainage areas with five acres of impervious surface. While smaller than the average of all evaluated sites, the priority sites were generally more cost-effective in terms of cost per impervious acre treated and the amount of pollutant (pounds of nitrogen) removed. The 12 priority projects averaged $18,350 per impervious acre treated; and, in terms of pollutant removal, the priority projects averaged just over 7.2 lbs of nitrogen removed per impervious acre. The average across all assessed sites was 1.5 times higher ($28,300 per impervious acre treated) and the removal per impervious acre slightly lower (6.8 lb of nitrogen).

Green Infrastructure Project: Kenhill Center. Kenhill Center is a former school and City Hall building in one of the older sections of Bowie. The Kenhill Center has office space for nonprofits and youth services, as well as a baseball and soccer field. The City estimates that approximately 60,000 to 70,000 people use or pass through the facility during a year. From the City's perspective, the high use and foot traffic makes it an ideal site for a demonstration and education project.

The proposed retrofit includes several green practices. To treat stormwater from the parking lot, a rain garden will be constructed. Bioretention will be installed at the facility's driveway entrance. In addition, bioswales with underdrains will be added to the sport fields and near existing concrete channels to capture runoff from stormdrain outfall and channel conveyance. The drainage area for this site is approximately 7 acres and just over 50% impervious. Collectively, the BMPs treat nearly all of the impervious surface.

The prioritization of projects – such as Kenhill – illustrate that stormwater expenditures are not driven solely by costs. While budget constraints and limited resources are a reality of public expenditures, local governments strive to make investments that are community-driven. Compared to the other projects in the top 12, the Kenhill project will be more expensive. However, the City selected this project because of its demonstration value. For a community facing more stringent regulatory requirements for stormwater and the challenges in gaining support for increased public expenditures towards that activity, the project's key role is to raise awareness and educate the community on the importance of managing stormwater. This focus lowered the interest and need for a holistic assessment of the project's benefits.

Case Study #3: Rockville, Maryland

About Rockville. Rockville, Maryland is a Phase II MS4 community located in Montgomery County, just north of Washington DC. Its municipal area is approximately 13 square miles and has a population of approximately 67,000. Approximately 13% of the city is zoned retail, industrial or office. The remaining area is zoned residential or mixed use and includes 950 acres of open space.

Annual Spending on Stormwater. Rockville has a dedicated enterprise fund for stormwater management. It budgets around $5 million per year in operating expenditures and capital improvement projects to address stormwater, including approximately 20 full-time employees. It relies primarily on revenue raised through a stormwater utility fee to fund most of these activities and services.

Approach to Stormwater Management. Rockville first received its NPDES permit in 2003. Its regulated area spans the entire municipality, excluding only impervious areas covered by an industrial NPDES permit and roads owned by MD State Highway Administration. The City is also the County seat. As a result, Rockville receives a fee from the County to treat county-owned impervious surfaces.

Rockville is almost completely built-out. However, the City has experienced strong economic growth, allowing redevelopment to drive much of the low impact design (LID) and green infrastructure (GI) in the municipality. Using post-construction standards, Rockville requires new development, redevelopment or infill to implement SW BMPs based on environmental site design (ESD) to the maximum extent practicable (MEP). The result has been the private sector delivering smaller scale, site-specific GI, such as green roofs, planter boxes, and bioretention facilities with over or underdrains.

The City anticipates having to invest in new or retrofitted stormwater BMPs once the new MS4 permit takes effect (in 2018). Under the current permit, the City has to undertake six MCMs. The new draft permit will require retrofitting existing development to address 20% of untreated impervious acres. The City plans to focus on larger-scale or regional facilities which will complement GI already being delivered through redevelopment.

Prioritizing Stormwater BMPs. The City has a strong tradition of stream stewardship that has played an important role in its approach to stormwater management. It has conducted watershed studies on a 10-year cycle since 1999. The watershed plans are the City's starting point for identifying and prioritizing work that addresses water quality and stormwater. These studies not only inform where to implement BMPs but also where to undertake stream restoration, habitat rehabilitation and SW retrofits. As a first screen for prioritizing spending on SW BMPs, Rockville focuses on areas of the streams that are in the greatest need for stabilization and restoration. The likelihood and scale of continued erosion and adverse impacts on public assets (regardless of being located on private or public land) will often drive prioritization rather than project costs.

The City then considers opportunities offering the greatest technical or watershed impact. Indicators of technical or watershed impact include the opportunity for treating the largest drainage areas and minimizing challenges in accessing and controlling the BMPs (eg, site availability and utility conflicts), as well as cost and treatment efficiency. This preference often translates into opportunities on public lands.

In both stream restoration and SW BMP implementation, community perceptions and acceptability play a third, but critical, role. The City gauges community acceptance based on potential recreational use impacts and impacts on existing natural capital (eg, wetlands and trees). These community considerations can lead to cost-effective projects being tabled. The importance of community considerations extends beyond the prioritization process. It also plays an important role in design decisions to ensure project success and the ability of a project to go beyond stormwater compliance to deliver recreational benefits and other amenities.

Green Infrastructure Project: Horizon Hill Stormwater Management Facility Retrofit and Stream Restoration. The Horizon Hill project is large-scale restoration and retrofit project located in the Watts Branch watershed. A priority watershed, the Watts Branch spans approximately 6.5 square miles of the municipality and has over 18 miles of stream. It is also characterized by development that occurred prior to modern stormwater management requirements.

The project uses a combination of grey and green BMPs to provide stormwater management for 165 acres of developed land with almost 50% impervious surface. It retrofitted the three dry ponds that were installed in the 1970s. Two of the three ponds were converted to wet ponds, and all three were updated with control measures to reduce maintenance requirements and improve performance reliability and extend their service reliability. Supplementing these changes, the project also created wetlands, restored 1,300 feet of stream (through floodplain reconnection and native plantings), and restored stream channels that drain approximately 100 acres.

The project is considered a success, enjoying strong community support and satisfaction. However, important contributors to this outcome were the emphasis on stakeholder engagement during the design of the project, and the project's maintenance plan. The City invested in forming partnerships with residents, civic and homeowner associations and environmentally concerned citizens. The site's maintenance involved aggressive non-native invasive management and control on approximately 12. 5 acres with the City committed to continue the management for five years after project completion. This effort is in addition to its as needed and routine garbage and landscaping maintenance activities.

Horizon Hill illustrates the hybrid approach that many municipalities employ in meeting stormwater compliance. Regulatory compliance achieved through municipal investments often leads to retrofitting existing development and/or SW infrastructure. Pure grey or green approaches will typically fall short in balancing financial constraints with community feedback. Instead, BMPs and upgrades will involve strategically mixing grey and green practices to achieve responsible, cost-effective water treatment while also looking to deliver community-determined amenities. It is not always apparent that the amenities associated with green infrastructure will be preferred (eg, local residents may need to be educated to understand how changes in landscape aesthetics or mowing practices, while not preferred, improve water quality and/or stormwater management). With strong, comprehensive and effective engagement, Rockville enabled the community to inform the design process, integrating recreational and aesthetic improvements. This engagement process meant the City did not have to document the value of these co-benefits but rather demonstrate that it is acting on the direction and values of the community's preferences.