Tools for Evaluating the Benefits of Green Infrastructure for Urban Water Management

INFORMATIONAL BRIEF
TOOLS FOR EVALUATING THE BENEFITS OF GREEN INFRASTRUCTURE FOR URBAN WATER MANAGEMENT

INFORMATIONAL BRIEF

by:
Emily Clifton
Neil Weinstein
Low Impact Development Center

2012
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Low Impact Development Center

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ABSTRACT AND BENEFITS

Abstract:

Communities are increasingly looking to green infrastructure as a means of meeting not only stormwater management objectives, but multiple environmental, social, and economic goals. Rather than viewing water infrastructure in isolation or – as has often been the case – an after-the-fact means of responding to a storm event or public health crisis, today’s urban planners are striving to integrate water treatment into their sustainable development goals. This report reviews the criteria, metrics, and protocols being used to measure such integrated systems.

Benefits:

♦ Identifies the practical challenges for evaluating the benefits of green infrastructure.
♦ Discusses a more systematic approach to integrate cost-effective, high-performance urban water infrastructure practices with other environmental, social, and economic goals.
♦ Provide examples of where life cycle cost and triple bottom line analyses are being used.

Keywords: Low impact development, LID, green infrastructure, life-cycle costs, triple bottom line, decision support criteria, stormwater management, urban water management.
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<tbody>
<tr>
<td>ACE</td>
<td>Army Corps of Engineers</td>
</tr>
<tr>
<td>APWA</td>
<td>American Public Works Association</td>
</tr>
<tr>
<td>AWWA</td>
<td>American Water Works Association</td>
</tr>
<tr>
<td>BMP</td>
<td>Best Management Practice</td>
</tr>
<tr>
<td>CSO</td>
<td>Combined Sewer Overflow</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse Gas</td>
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<tr>
<td>HUD</td>
<td>Department of Housing and Urban Development</td>
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<td>IRP</td>
<td>Integrated Resource Planning</td>
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<tr>
<td>LCCA</td>
<td>Life-Cycle Cost Assessment</td>
</tr>
<tr>
<td>LID</td>
<td>Low Impact Development</td>
</tr>
<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
</tr>
<tr>
<td>NPW</td>
<td>Net Present Worth</td>
</tr>
<tr>
<td>OP</td>
<td>Office of Planning</td>
</tr>
<tr>
<td>PBP</td>
<td>Payback Period</td>
</tr>
<tr>
<td>ROI</td>
<td>Return on Investment</td>
</tr>
<tr>
<td>SIMPLE</td>
<td>Sustainable Infrastructure Management Program</td>
</tr>
<tr>
<td>SWARD</td>
<td>Sustainable Water Industry Asset Resource Decisions</td>
</tr>
<tr>
<td>TBL</td>
<td>Triple Bottom Line</td>
</tr>
<tr>
<td>TP</td>
<td>Total Phosphorus</td>
</tr>
<tr>
<td>TSS</td>
<td>Total Suspended Solids</td>
</tr>
</tbody>
</table>
EXECUTIVE SUMMARY

Integrated wastewater management systems are viewed as more environmentally and economically sustainable and effective manners of controlling runoff than traditional stormwater management practices. Unlike traditional wastewater management which treats rainwater as something to be collected and disposed of as quickly as possible, integrated wastewater management systems incorporate processes that mimic nature – often referred to as green infrastructure or low impact development practices – to capture and treat rain and runoff as close to the source as possible and allow it to either infiltrate into the soil for natural treatment through evapotranspiration, or be reused for some other benefit such as cooling water. In doing so, such techniques help prevent or reduce the volume of urban runoff entering our streams and waterways and provide other benefits such as enhanced pollutant removal, reduced flooding, public health benefits, increased open space, and improved quality of life.

Although more and more cities and counties are embracing the concept of green infrastructure and the application of these practices is growing rapidly, data regarding costs, effectiveness, and additional benefits is still limited. In 2007, the U.S. EPA issued a report that evaluated 17 developments incorporating green infrastructure and found that, for the vast majority, the implementation of such practices was shown to be both fiscally and environmentally beneficial, with total capital cost savings ranging from 15-80%. In the cases where initial costs were lower than traditional approaches, projects benefitted from requiring less piping and underground infrastructure, less grading and preparation costs (resulting from open space protection and cluster development), and less paving (U.S. EPA, 2007). In other cases, however, upfront costs associated with the installation of green infrastructure practices have been found to be higher – compared to some traditional infrastructure practices when assessed solely as stormwater controls.

Where data is lacking, or where higher initial costs prevail, city and county managers are often reluctant to pursue green infrastructure options. To overcome this, more emphasis is being placed on evaluating benefits and costs over the life of the project using business metrics such as life cycle cost analysis and triple bottom line assessments. This report provides an overview of both and the ways in which communities are using more rigorous analysis to build a case for green infrastructure and integrated stormwater management.
CHAPTER 1.0

INTRODUCTION

1.1 Introduction

A multitude of water challenges confront today’s urban communities. Faced with aging and inadequate water infrastructure, growing water demand and flooding concerns, and uncertainties due to the impacts of climate change, city planners are changing the way they think about water infrastructure systems. Rather than viewing water and stormwater infrastructure in isolation, some urban communities are striving to integrate urban water issues into larger community goals. Stormwater practices such as green infrastructure or low impact development (LID) that use or simulate the actions of natural systems to limit the conversion of precipitation to runoff are increasingly being seen as viable alternatives for either complementing or replacing traditional stormwater technologies, as well as reducing flooding risks, improving water quality, protecting source water, and providing for the natural replenishment of groundwater aquifers. By moving to more integrated systems that better mimic nature, it is expected that water and other community infrastructure issues can be better managed over the long-term in a cost-effective manner.

Measuring the impact of integrated systems, however, requires a different framework or set of operational procedures. In the context of stormwater infrastructure, in particular, there is a movement towards incorporating better measures in order to evaluate the full cost and benefit of implementing traditional versus “greener” stormwater infrastructure practices.

This report provides overviews for two sustainable business metrics gaining popularity in the urban planning field – life cycle cost assessments and triple bottom line – as they apply to stormwater and urban water management. It outlines some of the practical challenges encountered when collecting data and measuring for performance. It also provides examples of cities such as Philadelphia, PA and Washington, D.C. that have begun to embrace a more systematic approach to water management in order to provide guidance to others who are interested in developing similar initiatives.
CHAPTER 2.0

PRACTICAL CONSIDERATIONS: EVALUATING THE VALUE OF GREEN INFRASTRUCTURE

2.1 Green infrastructure’s Role in Urban Water Management

Over the past few decades, a fundamental shift has taken place in the way in which we view water and wastewater management in urban environments. Stormwater infrastructure, once considered as an after-the-fact means of responding to a flood event or public health crisis, is increasingly becoming a top concern for urban municipalities, and green infrastructure is increasingly becoming a recognized tool for addressing water concerns in large metropolitan areas. Green infrastructure and low impact development (LID) – used interchangeably throughout this document – are distributed stormwater management techniques that use or simulate the actions of natural systems to limit the conversion of precipitation to runoff, thus shifting the focus from remediation to prevention and reuse. Green infrastructure techniques capture and treat rainwater as near as possible to where it falls in order to reduce both pollutant loads and the amount of stormwater entering the collection system. In older urban areas built prior to the existence of separate stormwater controls, green infrastructure can help to reduce pollutant concentrations and runoff volumes. Where combined sewer overflows (CSOs) exist, green infrastructure’s primary benefit is to reduce runoff volumes and the burden placed on the collection system. Through green infrastructure, both the frequency and volume of CSO events can be reduced (Weinstein et al., 2009).

Integrated wastewater management systems that mimic nature are viewed as more sustainable and effective manners of controlling runoff than traditional end-of-pipe practices. In contrast to grey infrastructure – which refers to traditional stormwater management approaches that typically involve curbs, gutters, pipes, and containment and treatment facilities – green infrastructure can provide multiple environmental, social, and economic benefits (CNT, 2010a; U.S. EPA, 2007; Foster et al., 2011). Key to helping municipalities adopt such practices, however, is the ability to monetize such values. This requires evaluating the costs of installing green infrastructure over conventional practices; evaluating long-term operation and maintenance costs; and quantifying and monetizing other social, environmental, and economic benefits (ECONorthwest, 2007; CNT, 2010a). Doing so better enables municipalities to adopt and implement green infrastructure technologies for capital investment projects.

2.2 Practical Challenges for Evaluating the Value of Green Infrastructure

While the past several years have seen an increase in studies attempting to place a value on green infrastructure versus traditional practices, most only look at either an individual benefit or set of benefits (such as stormwater, heat island effect, or increased property value benefit) of a particular practice. Very few take an all-encompassing approach due to the difficulty in assigning values. This, in turn, limits the ability to which a green infrastructure approach can be evaluated against other alternatives (CNT, 2010a). There are practical challenges to conducting such an analysis, including:

♦ The ability to articulate problem, goals, and objectives
♦ The ability to coordinate services amongst traditionally separate departments
- The availability and transferability of performance data
- Ensuring quality and consistency of monitoring efforts
- Quantifying and attaching monetary values
- The effort required to gather data

### 2.2.1 Ability to Articulate Problem, Goals, and Objectives

While green infrastructure can help achieve multiple goals, the utility of individual practices depends on the overarching goal(s) a community is trying to achieve. Such goals may include the following:

- Addressing flooding concerns, water availability, or climate change
- Strengthening local economic development
- Encouraging neighborhood stabilization

When considering the use of green infrastructure, it is important to first identify the problem(s), establish appropriate goals and milestones, determine which green infrastructure practices are most appropriate to meet the community’s goals, and initiate an ongoing dialogue with identified stakeholders. One planning approach that works particularly well for water infrastructure concerns is a watershed approach. By viewing planning issues watershed-wide, as opposed to limiting planning to a community’s jurisdictional boundaries, all the major factors affecting water use and water protection can be viewed comprehensively. Several publications on watershed planning are available that provide general guidelines in the planning process (see: U.S. EPA, 2008; TetraTech, undated; Stephens et al., 2002). Figure 2-1 identifies and describes the six general steps in the watershed planning process, as put forth by the U.S. EPA (2008).

Another planning approach that is gaining in popularity for stormwater and local water resource management is integrated resource planning (IRP). The IRP approach, which is a modified version of watershed planning, lends itself to more diverse, complex planning needs by recognizing the increasingly intense competition for water use and threats to water quality. IRP places greater emphasis on flexibility and inclusiveness, and emphasizes the evaluation of multiple planning scenarios where key assumptions can be altered, such as fluctuations in temperatures or water levels due to anticipated climate change effects. IRP also strives to provide a more holistic understanding of water use than traditional watershed planning by providing emphasis on not just the hydrological functioning of watersheds but the environmental, social, and economic functions (AWWA, 2007; Lindsey, 1996).

Recently, the Center for Neighborhood Technologies launched the “Great Lakes Sustainable Water Planning Project” to determine how IRP can improve economic efficiencies within water utilities (CNT, 2010). Similarly, the Metropolitan Water District of Southern California has utilized the integrated resource planning process since 1996 to develop and maintain a long-term water plan to attempt to protect the region from water supply shortages, with an emphasis on water-use efficiency through conservation and local supply development (MWDSC, 2010).
2.2.2 Ability to Coordinate Services Amongst Traditionally Separate Departments

Green infrastructure must not only work in combination with traditional gray infrastructure, but due to its multiple benefits, there is a strong need for people within city departments to coordinate activities both to strengthen programs, reduce duplication, and help fund installation and maintenance (CWWA, 2010). In the City of Detroit, MI, for example, the Detroit Water and Sewerage Department, which is grappling to pay for green infrastructure programs as part of its alternative CSO control plan, is working to install green infrastructure projects in areas of Detroit...
in need of stabilization, such as schools, to complement efforts by the Department of Housing and Urban Development’s (HUD) Neighborhood Stabilization Project, which is focusing on areas of the community where blight is an issue. Both approaches will help to remove vacant structures from the sewer system and replace them with pervious surfaces. By working with HUD, DWSD will be able to accomplish more than it could on its own (Garrison et al., 2011).

### 2.2.3 Availability and Transferability of Performance Data

Measuring multiple benefits requires information not only on the environmental performance of green infrastructure practices, but social and economic performance as well. For environmental performance, the International Stormwater BMP Database (www.bmpdatabase.org) serves as the primary source for Best Management Practice (BMP) performance data (Wright Water Engineers and Geosyntec Consultants, 2009). Other sources, such as the 2004 Water Environment Research Foundation report on Post-Project Monitoring of BMPs/SUDS to Determine Performance and Whole-Life Costs (Weinstein et al., 2004) and the U.S. EPA’s web-based Urban BMP Performance Tool (available at www.epa.gov/npdes/urbanbmptool), are also a good starting point for stormwater professionals in need of literature reviews and research studies on green infrastructure practices.

Long-term data supporting performance metrics for particular BMPs, however, are not always readily available. Furthermore, numerically reported efficiencies are often site-specific, can fluctuate between storm events, and potentially are non-transferable. This means that numerically reported performance values should be considered as general estimates on how well practices would perform, and that design modifications might be required in for practices to perform as designed, based on environmental constraints particular to specific area (Muthukrishnan et al., 2004). As an example of how one municipality dealt with this issue, Portland, OR, formed a Sustainable Stormwater Management Program, which, amongst other things, monitors and tests the performance of demonstration projects in order to quantify performance benefits and improve the design and function of green infrastructure practices for use within Portland (more information can be found by viewing WERF’s Livable Communities case study report for Portland at www.werf.org/livablecommunities/).

### 2.2.4 Ensuring Quality and Consistency of Monitoring Efforts

Research and monitoring on individual sites show that green infrastructure practices, when properly designed, installed, and maintained, reduce runoff volumes and remove total suspended solids and pollutants such as nutrients and heavy metals. But monitoring for effectiveness is complex, and data availability for individual practices varies. Many of the monitoring methods related to stormwater BMP performance are designed to evaluate traditional stormwater management practices. Green infrastructure practices, however, are based on a water balance approach, are often placed in a series, and their design properties are influenced by temporal and spatial variations. Great variability in stormwater properties and the associated runoff complicates BMP monitoring further. What this means is that, even when monitoring data is available, the reliability of the information may be questionable and the ability to collect the information consistently over a given time period may be difficult.

To overcome this issue, in 2009, a guidance document entitled, Urban Stormwater BMP Performance Monitoring – A Guidance Manual for Meeting the National Stormwater BMP Database Requirements was issued through the International Stormwater BMP Database project. It provides a recommended set of protocols and standards for the collection, analysis, and reporting of water quantity and quality measurements, with emphasis on monitoring green infrastructure practices. Similarly, societal and economic benefits of green infrastructure should
be measured over time in order to improve accuracies in assessments. Adhering to standardized measures over time can improve the utility of performance measures by allowing performance of individual practices over time to similar practices installed in areas with similar environmental, social, or economic characteristics.

2.2.5 Quantifying and Attaching Monetary Values

There exist a limited but growing number of economic studies quantifying the benefits from implementing LID and green infrastructure technologies (see Sample et al., 2003; Powell et al., 2005; CRI, 2005; U.S. EPA, 2007). In addition, most existing studies describe only the cost of installing LID, or compare those costs with conventional controls, but fail to evaluate long-term operating and maintenance costs (EcoNorthwest, 2007).

In 2007, the U.S. EPA released a case study analysis of 17 different developments showed that applying green infrastructure techniques reduced project costs and improved environmental performance. Capital cost savings gained from using such practices were found to range from 15-80%. Results from the analysis of development costs provided in the report are show in Table 2-1. Note that five of the 17 case studies are not included in the table because the development projects did not lend themselves well to a conventional versus green infrastructure cost comparison. For the one project where LID Costs were higher – Kensington Estates – the increases costs were associated with a rooftop runoff collection system, which served to approximately double the costs. Without the rooftop collection system, however, the costs associated with the LID design were actually a little less as compared to the conventional development ($678,900 versus $765,700) (CH2M HILL, 2001).

<table>
<thead>
<tr>
<th>Project</th>
<th>Conventional Development Cost</th>
<th>LID Cost</th>
<th>Cost Difference</th>
<th>Percent Difference</th>
</tr>
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<tr>
<td>2nd Avenue SEA Street, Seattle, WA</td>
<td>$868,803</td>
<td>$651,548</td>
<td>$217,255</td>
<td>25%</td>
</tr>
<tr>
<td>Auburn Hills Subdivision, Southwest WA</td>
<td>$2,360,385</td>
<td>$1,598,989</td>
<td>$761,396</td>
<td>32%</td>
</tr>
<tr>
<td>Bellingham City Hall Parking Lot, WA</td>
<td>$27,600</td>
<td>$5,600</td>
<td>$22,000</td>
<td>80%</td>
</tr>
<tr>
<td>Bellingham Bloedel Parking Lot, WA</td>
<td>$52,800</td>
<td>$12,800</td>
<td>$40,000</td>
<td>76%</td>
</tr>
<tr>
<td>Gap Creek Subdivision, Sherwood, AR</td>
<td>$4,620,600</td>
<td>$3,942,100</td>
<td>$678,500</td>
<td>15%</td>
</tr>
<tr>
<td>Garden Valley, Pierce County, WA</td>
<td>$324,400</td>
<td>$260,700</td>
<td>$63,700</td>
<td>20%</td>
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<tr>
<td>Kensington Estates, Pierce County, WA</td>
<td>$765,700</td>
<td>$1,502,900</td>
<td>-$737,200</td>
<td>-96%</td>
</tr>
<tr>
<td>Laurel Springs Subdivision, Jackson, WI</td>
<td>$1,654,021</td>
<td>$1,149,552</td>
<td>$504,469</td>
<td>30%</td>
</tr>
<tr>
<td>Mill Creek Subdivision, Kane County, IL</td>
<td>$12,510</td>
<td>$9,099</td>
<td>$3,411</td>
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<tr>
<td>Prairie Glen Subdivision, Germantown, WI</td>
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<td>$599,536</td>
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<td>Somerset Subdivision, Prince George’s County, MD</td>
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<td>$1,671,461</td>
<td>$785,382</td>
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<td>Tellabs Corporate Campus, Naperville, IL</td>
<td>$3,162,160</td>
<td>$2,700,650</td>
<td>$461,510</td>
<td>15%</td>
</tr>
</tbody>
</table>

Notes: a Five case studies included in the U.S. EPA report did not lend themselves to a cost comparison analysis. b Negative values denote increased costs for LID over conventional development design. c Numbers for Mill Creek are reported on a per-lot basis.
Information on socio-economic benefits, which only recently began receiving more interest, can also be difficult to assess. Several existing publication, however, serve as an excellent starting point for obtaining such information. Lampe et al. (2005) document the whole-life costs and operational performance of a variety of LID BMPs, and WERF has published and built upon the whole-life cost models used in this analysis. Spreadsheet models are available for the major LID BMPs (WERF, 2009), and through its Sustainable Infrastructure Management Program Learning Environment (SIMPLE) program, WERF is developing tools and resources to make information on costs of both traditional and green infrastructure more readily available to decision makers (WERF, 2011).

In addition, a recent publication by the Center for Neighborhood Technologies (2010a) provides information on the value of green infrastructure’s multiple benefits, and a 2007 literature review published by EcoNorthwest on the economic costs and benefits of managing stormwater using green infrastructure/low impact development. Lastly, a recent triple bottom line assessment of green infrastructure in Philadelphia provides references to various social and economic analyses related to different green infrastructure practices (Stratus Consulting, 2009).

Unit costs data on construction costs can be obtained from the latest RS Means Building Construction Cost Data (Sample et al., 2003).

2.2.6 Effort Required to Gather Data

While in most cases it is possible to gather necessary data, doing so might require more time, effort, or cost than an agency is able or willing to spend. For example, to determine green infrastructure’s value within the community, Philadelphia, PA, conducted a study on the willingness of residents to pay for such programs to treat runoff from 50% of the city’s impervious areas, and found that households would be willing to pay $10-16 per year. Over a 40-year analysis period, the total estimated value equates to $330 million (Stratus Consulting, 2009). Other cities, however, might not necessarily have the funds or time to expend on this or other surveys where data is lacking.
CHAPTER 3.0

MEASURING THE APPLICABILITY AND COST EFFECTIVENESS OF GREEN INFRASTRUCTURE: EVALUATION TECHNIQUES

3.1 Calculating Green Infrastructure’s Value

Green infrastructure is gaining priority as a means to reduce stormwater volume, improve water quality, conserve water resources, and reduce flooding, as well as additional social and economic benefits, such as improved aesthetics and community livability. Key to helping municipalities adopt such practices is the ability to quantify costs and economic values. However, most existing studies only consider green infrastructure’s installation costs, or compare those costs with the costs of installing conventional controls, but fail to either evaluate long-term operating and maintenance costs or quantify the other economic benefits it can provide (EcoNorthwest, 2007). A need exists to quantify and monetize the pollution prevention benefits and avoided treatment costs gained from the use of such techniques.

Several techniques exist for measuring cost effectiveness. When evaluating stormwater practices, for example, WERF (2010) identified the following five techniques as the most appropriate for measuring the benefits and costs of green infrastructure against more traditional infrastructure systems: damage cost avoided, lifecycle cost analysis, benefit cost analysis, productivity method, and hedonic pricing method. A more detailed discussion of each, including their strengths and weaknesses, is available on WERF’s Livable Communities website.

This report focuses on two sustainable business metrics highlighted for use for urban water management – triple bottom line and life cycle cost assessments – to measure the full return on investment for specific projects. Instead of focusing on short-term costs and returns, such metrics attempt to determine whether various green infrastructure alternatives are economically feasible by measure their benefits as compared to traditional options through full cost accounting. These metrics allow broader environmental, social, and economic benefits to be incorporated into long-term municipal stormwater planning when evaluating the suitability of different management alternatives (Powell et al., 2005).

3.2 Triple Bottom Line Assessment

Coined in the 1990s, the concept of the triple bottom line (TBL) assessment was initially proffered as a way for businesses to think and report about sustainability. Since then, its popularity has made its way into other fields, such as urban water management, overtaking the use of other similar assessment techniques, such as environmental impact assessments and social impact assessments, as a means to evaluate the environmental, social, and economic benefits of projects (Vanclay, 2004), with a heavy emphasis on public participation (Taylor and Fletcher, 2003).
In terms of water management, the TBL approach provides a means by which water managers can focus on optimizing the whole system, as opposed to individual components of stormwater, drinking water, and sewage (Novotny and Brown, 2007; Farah, 2008). This can be attained by implementing green infrastructure or low impact development practices to reduce volume and peak flows and allow for water to be treated and stored on site; by reducing imperviousness and increasing tree canopy cover and riparian corridors; and by applying water and energy conservation techniques at the building level (Farah, 2008). The benefits of applying a TBL approach to water and stormwater management include:

- Better articulating and aligning a program’s problem, goals, and objectives (see Section 2.2.1)
- Improving communication and stakeholder relations
- Engaging experts and stakeholders from multiple fields
- Evaluating benefits and trade-off from multiple perspectives, both quantitatively and qualitatively (Taylor and Fletcher, 2005)

While no universally accepted standard method exists for calculating the TBL or for selecting the measures that comprise each of the three TBL categories (Slaper and Hall, 2011), a TBL assessment guide was developed to assist urban stormwater managers in Australia (Taylor, 2005; Taylor and Fletcher, 2005). In addition, a European assessment guideline prepared as part of the Sustainable Water industry Asset Resource Decisions (SWARD) project also exists (Ashley et al., 2003). Because the three categories (environmental, social, economic) can include both quantifiable outcomes that are reasonably well monetized, and qualitative outcomes that are hard to monetize, TBL accounting doesn’t necessarily include a common unit of measure. Such flexibility allows a user to adapt the framework to its specific needs and incorporate public participation into the planning and decision-making process, and can be an attractive alternative to cost-benefit analyses that attempt to monetize all benefits (Taylor and Fletcher, 2003). This same flexibility, however, can also result in uncertainty as to how the pieces all fit together. The following are a list of recommended economic, environmental, and social criteria to be utilized in TBL assessments for green infrastructure projects, as modified from lists provided by Boyd and Kimmet (2005), Slaper and Hall (2011), and the DC Office of Planning (2011).

### 3.2.1 Environmental Criteria

In a TBL approach, environmental criteria refer to an evaluation of natural resources. While individual metrics or measurements will vary based on the needs or focus of the project, for such measurements to be meaningful, they should measure potential influences to the viability of natural resources (Slaper and Hall, 2011). Potential environmental metrics include:

- Impervious surface reduction
- Stormwater volume reduction and stormwater flux
- Groundwater recharge
- Water consumption
- Recycling opportunities
- Sulfur dioxide concentrations
- Excessive nutrients
- Wildlife habitat benefits
3.2.2 Social Criteria

Social criteria attempt to measure the social dimensions of urban water projects and can include quality of life measures, access to resources, and social capital. Sample criteria include:

- Ability to serve as a “green” reference point
- Neighborhood connectivity
- Aesthetic implication
- Public access to water or other environmental feature
- Average commute time
- Violent crimes per capita
- Health-adjusted life expectancy
- Unemployment rate
- Female labor force participation rate
- Median household income
- Relative poverty

3.2.3 Economic Criteria

Economic criteria measure the “bottom line” and economic benefit to the community. Sample criteria include:

- Avoided stormwater treatment costs
- Avoided energy use
- Property values
- Personal income
- Cost of underemployment
- Local “green” job growth
- Employment distribution by sector
- Revenue by sector contributing to gross state product

3.3 Life Cycle Cost Assessment

Life-cycle cost assessments (LCCA) help municipalities in making informed decisions about infrastructure investments by factoring in the full costs and risks of different projects. LCCA considers all project costs derived from the planning, design, construction, operation, and disposal of a particular project alternative (Powell et al., 2005). As described by Sample et al. (2003), the life cycle costs associated with stormwater management include an evaluation of the initial capital costs, annual operation and maintenance costs over time, minus its value at the end of its service life. Pending available data, an LCCA can help determine the affordability of green infrastructure projects as part of, or as an alternative to, traditional stormwater controls and provides a framework for evaluating
In an attempt to be holistic, LCCA calculation procedures can become complex, thus increasing the likelihood of mistakes. To deal with this, the International Standards Organization developed a standardized method for life cycle assessments in 1996. In it, the ISO 14040 series standards includes major procedural steps for comparing process and product alternatives (Kirk et al., 2006; SAIC, 2006). These include:

- **Goal Definition and Scoping** – Define and describe the objectives; establish the context; and identify the boundaries and environmental effects to be reviewed.
- **Life Cycle Inventory Analysis** – Identify and catalogue the resources used.
- **Life Cycle Impact Assessment** – Assess the potential human and ecological effects of energy, water, and material usage and the environmental releases identified in the inventory analysis.
- **Interpretation** – Evaluate the results to determine the level of certainty based on assumptions used.

### 3.3.1 LCCA Tools

In calculating costs, several worksheets or set of worksheets are available to help guide municipal managers through the process, such as the BMP and LID Whole Life Cost Models (Version 2.0) published by WERF (2009); a Comprehensive Cost Estimating Worksheet developed by LMI Government Consulting (Powell et al., 2005); an example of a simple life cycle cost model for a hypothetical wetland in Australia (Taylor, 2003); and an example of a life cycle cost estimate for a green roof available in Indianapolis, IN’s Draft Green Infrastructure Supplemental Stormwater Document (2009). However, these examples limit their focus to operational and maintenance costs related to stormwater and do not attempt to include cost estimates for additional environmental benefits such as water quality improvements, or socio-economic benefits such as public safety or recreational values.

While developed for the UK, another LCCA cost estimate tool worth looking at is Eco.SWM – an excel-based application with access to a web-based database of unit prices, operational cost per unit, and lifetime expectancy for different measures (SWITCH, 2008). Were a similar tool with access to unit costs and performance data developed for the U.S., municipal managers would have a much easier time preparing life cycle assessments. Currently, WERF is developing an Excel-based life cycle costing tool to help municipalities and others determine life cycle and replacement costs as part of its SIMPLE project. This table will enable organizations to collect historical life cycle cost data to project future cost trends. Drexel University is also currently developing an open source, web-based tool to allow users to compare life cycle costs for various green infrastructure practices (Montalto and Waldman, 2010).

### 3.4 Examples of TBL and LCCA in Use

The following are examples of where the concepts of triple bottom line and life cycle cost analyses have been put into use to address urban water and stormwater concerns. One study (see Boston example) utilizes both approaches, while others utilize one.
3.4.1 Boston Example: TBL and LCCA for Integrated Resource Planning

The first example comes from a study to evaluate the feasibility of sustainable development in Boston to determine the economic viability of an integrated resource plan for 21 hydrologically independent urban clusters or “ecoblock” configurations ranging in size from small, community-like clusters to large, urban hubs in the southern part of Boston. In it, Farah (2008) utilized both a TBL and LCCA approach to evaluate the use of various water and energy conservation techniques in order to determine which techniques or combination of techniques could result in the most holistic and sustainable use of water, where the amount of water leaving the system is minimized and water reuse and recycling are maximized. The study evaluated the optimization of various water and energy BMPs at both the building level and urban cluster scale. Evaluated BMPs included efficient home appliances for water and energy conservation, green roofs for stormwater retention and building insulation, the building of water reclamation facilities to enable more efficient water reuse, and use of alternative energy sources via heat extraction from wastewater. While the importance of LID techniques such as rain gardens, bioswales, underground storage tanks, and pervious pavement were noted, the use and benefits of such BMPs were ultimately not evaluated due to the scale at which the study took place, and the lack of such detailed, parcel-specific information. While completed as part of a Master thesis for Northeastern University’s Department of Civil and Environmental Engineering, this study provides a good case study for urban communities interested in evaluating the feasibility of adopting a development model which encourages a more holistic approach to water management.

BMPs were placed into four different categories: water and energy conservation; green roofs; water supply, reclamation, and reuse; and alternative energy use. To evaluate environmental benefits, Farah calculated annual water and energy savings, peak flow reductions for the one-year, six-hour storm, and offset greenhouse gas (GHG) emissions. In general, the amount of water retained by installing green roofs was shown to exceed the volume that can be saved through the use of water conserving appliances and fixtures, highlighting their importance in reducing stormwater runoff. Where peak flow reductions could be estimated, percent reductions ranged from 10.2-32.8% (peak flow reductions were only estimated for Ecoblocks 1-11 and Ecoblock 21; peak flow reductions for the remaining Ecoblocks, which were combinations of Ecoblocks 1-11, were not computed).

Social benefits were calculated by estimating savings in water and electricity bills, while unquantifiable social benefits included changes in property value, improved air quality, and reduced localized flooding. Economic benefits were evaluated by estimating the benefits of sustainable development from:

- Water supply (conservation + reuse)
- Wastewater treatment (conservation + reuse)
- Energy (conservation + alternative energy sources)
- Energy (green roofs)

While the use of green roofs contributed to higher savings in wastewater treatment, the largest energy savings by far – about 95% – came from the application of efficient indoor appliances and alternative energy sources. What this means is that, while green roofs were shown to be important for reducing stormwater runoff and reducing the need for such runoff to be treated at a water reclamation plant, from an energy standpoint, green roofs did not provide a
significant source of savings. A complete list of tables as well as information on the sources used to compute benefits can be found by viewing the full report, which is available online.

Using the information obtained through the TBL process, a LCCA was then performed in order to calculated the net present worth (NPW) and payback period (PBP) for the various alternatives. The purpose of this analysis was to determine whether the savings generated from implementing the identified BMPs outweigh the investment – an issue identified by Farah as of particular interest to potential developers in order to determine whether a proposed plan is economically viable. Through the LCCA process, five different scenarios were evaluated:

- **Scenario 1**: A *green roof-centric* approach where only green roofs were installed
- **Scenario 2**: An *energy-centric* scenario, where green roofs were coupled with energy conservation efforts
- **Scenario 3**: A *comprehensive* approach, where green roofs were combined with decentralized water reclamation facilities, water and energy conservation, and alternative energy sources
- **Scenario 4**: A *water-centric* approach, where green roofs were combined with other water conservation, reclamation and reuse efforts
- **Scenario 5**: A *conservation-centric* approach, where no green roofs were applied but instead relied on other water and energy conservation practices.

Results from the LCCA showed both Scenarios 1 (green roof-centric) and 4 (water-centric) to be unfeasible. Using a cost estimate of $10.85/ft² for a widespread green roof application, the NPV for the green roof only approach (Scenario 1) was found to be negative for all 21 urban clusters. This means that the cost of investment of green roofs on their own could not be recovered during their life cycle. In fact, the PBP was estimated to be 63 years, or 23 years beyond a green roof’s expected service life. When the green roofs were coupled with direct energy savings from energy conservation measures in Scenario 2, however, the NPV was positive for all clusters, with a PBP between 10.5-35 years.

Likewise, in Scenario 4, which excluded energy conservation measures and only incorporated BMPs focused on water management, all NPVs were negative. Taking out green roofs as an alternative (Scenario 5), the NPVs turned positive, with PBPs as low as 2-3 years, thus showing the conservation-centric approach to be the most profitable alternative. Of greatest interest from a city planning perspective, however, was Scenario 3 – the comprehensive approach, where green roofs, decentralized water reclamation facilities, water and energy conservation, and alternative energy sources were combined. This scenario was also determined to be feasible, with a PBP between 13-22 years for the various urban clusters. Farah also notes that, for areas of the country where water shortages aren’t an issue, a water-centric policy may need a certain element of energy efficiency to render it economically feasible. In addition, addressing both comprehensively may be the most economically viable solution, further emphasizing the need for stormwater and urban water managers to work cooperatively with sustainable building programs to achieve more for less (Farah, 2008).

### 3.4.2 City of Mission Example: LCCA for Rock Creek

For many communities, stormwater management issues are being brought to the forefront due to concerns with aging infrastructure, water quality, and stream bank flooding and erosion, and compliance with the National Pollutant Discharge Elimination System. Such concerns are motivating cities to prioritize capital expenditures that utilize green infrastructure and LID as
part of their comprehensive urban planning and design approach, and to adopt new design standards allowing for their use (Black and Veatch, 2009).

In 2009, the U.S. Army Corps of Engineers (ACE) commissioned an Alternative Futures study for the Rock Creek Watershed, which lies within the Kansas City metropolitan area, in order to compare the use of LID scenarios to traditional development scenarios via a life cycle cost analysis, with the results to benefit the City of Mission, Kansas. The City is an NPDES Phase II community with an older, degraded, and undersized secondary drainage collection system. At the time the City of Mission was getting ready to adopt the regional American Public Works Association (APWA) Manual of BMPs for Stormwater Quality (MARC, 2008), which would require limiting peak discharge from the 1-, 10-, and 100-year storm events to predevelopment peak flows to prevent flooding, regardless of whether LID or traditional stormwater management practices are used. Additional City criteria require that runoff from improved impervious areas on all development or redevelopment sites larger than 0.5 acres not exceed the runoff under unimproved conditions. This requirement was typically met by detention.

Three sites were selected to evaluate the use and cost effectiveness of LID in urban retrofits or redevelopment in the City of Mission: one mixed-use commercial redevelopment, one multifamily development, and one single-family residence. Two LID scenarios were prepared for each development type. In LID Scenario 1, the site was designed to meet the regional APWA Manual of BMPs for Stormwater Quality, as well as regional stormwater drainage design standards. In LID Scenario 2, the site was designed to meet the APWA BMP manual design standards and exceed the regional stormwater drainage standard’s peak discharge and total runoff volume requirements. An LCCA was then conducted and the NPV of capital and maintenance costs and return on investment (ROI) were calculated for each scenario to evaluate the costs over a 50 year period. Each scenario’s ability to improve water quality was evaluated using the P8 Urban Catchment Model. Total suspended solids (TSS) and total phosphorus (TP) concentrations were used as water quality improvement indicators to evaluate the potential cumulative removal of suspended and dissolved contaminants over the course of a year.

For the mixed use development site, the resulting LID Scenario 1 site design resulted in the optimal amount of water quality benefits and ROI. In addition, for this site, only one LID scenario was prepared, as application of the APWA BMP Manual requirements for Scenario 1 resulted in a design that also met the peak discharge and total runoff requirements for Scenario 2 (see Figure 3-1).
Note: Manual requirements for Scenario 1 resulted in a design that also met the peak discharge and total runoff requirements for Scenario 2. As such, a second LID scenario was not required.

Figure 3-1. Cost Benefit Comparison of Mixed-Use Development Scenarios. (Black and Veatch, 2009)

Figures 3-2 and 3-3 provide the scenario results for multi-family development and residential sites. Note that, for the residential development (Figure 3-4), no traditional development scenarios were prepared. This was because the City did not have stormwater management guidance criteria for single lot redevelopments. For all three sites, LID Scenario 1 was identified as the preferred alternative because of 1) a significant improvement in water quality benefits, 2) satisfaction of the peak discharge and total runoff requirements, and 3) the ROI and capital expenditures were comparable to the traditional development. As a result, this study recommended revisions to the city’s existing codes to adopt stormwater quality best management practices that would not only allow but require improved stormwater management strategies for the future (Black and Veatch, 2009).
Figure 3-2. Cost Benefit Comparison of Multi-Family Development Scenarios. (Black and Veatch, 2009)

Figure 3-3. Cost Benefit Comparison of Residential Scenarios. (Black and Veatch, 2009)
3.4.3 Washington, D.C. Example: TBL for New York Avenue

The second TBL-only example comes from Washington, D.C., and provides an example of how such a process has been applied more simplistically at the project level to aide planning staff in prioritizing potential green infrastructure projects. In 2010, the District of Columbia Office of Planning (OP) initiated an assessment to identify and develop a green infrastructure master plan along a portion of New York Avenue NE, with the goal being to develop an environmentally progressive and sustainable foundation for infrastructure and development to occur along the corridor. A key element of the assessment was to develop strategies to implement green infrastructure techniques into existing and proposed infrastructure, with a focus on reducing stormwater runoff, improving water quality, and providing ancillary economic, social, and other environmental benefits (DC Office of Planning, 2011).

To accomplish this, the Office of Planning (OP) incorporated a modified triple bottom line approach into their site selection criteria, and ranked and prioritized 18 projects based on 19 metrics, both qualitative and quantitative in nature, broken into their social, economic, human health, and environmental components. Criteria and metrics utilized include the following:

- Project Parameters: Criteria such as property ownership and location which are important for determining the ease in which a project can be implemented
- Social Benefits: Criteria to determine whether the potential project is in conformance with existing plans, and whether or not acts as a visible reference point for the community
- Human Health: Quantitative criteria to assess whether human health is positively affected
- Environmental Function: Included to evaluate the ability of the project to meet the District’s water quality goals, as well as to reduce the District’s carbon footprint, both of which are high priorities.
- Economic Benefit: Criteria to measure the ability of potential projects to provide for green jobs, positively affect property values, or reduce stormwater management costs.

Whereas a “true” triple bottom line approach divides criteria solely into environmental, social, and economic categories, for the purpose of ranking and weighing various criteria, the environmental criteria was broken into two categories (e.g., environmental criteria relating to stormwater flow and quality weighed more than environmental criteria related to human health). Also of interest is the evaluation of the project’s relative ease to implement (Project Parameters) which was also incorporated into the ranking process.

3.4.4 Philadelphia Example: TBL for CSO Planning

In 2009, Philadelphia released a $1.6 billion “Green Cities Clean Waters” Plan to control CSOs through a comprehensive watershed-based approach, which includes a combination of green and grey infrastructure techniques (Philadelphia Water Department, 2009). Approved by the U.S. EPA in 2011 (Clark, 2011), the plan places emphasis on incorporating green infrastructure features and replacing impervious surfaces with green areas throughout its 63 square mile combined sewer service area (Philadelphia Water Department, 2009).

To evaluate green infrastructure and traditional stormwater techniques, Stratus Consulting conducted a TBL analysis of various CSO alternatives, later combined with engineering cost information. For each watershed within the CSO control area, a range of possible low impact development CSO control options were measured to evaluate the impact of different implementation levels (with 25, 50, 75, and 100% of runoff from impervious surfaces
managed through green infrastructure). Scenarios were evaluated using a TBL assessment to determine the level of benefits anticipated for the following categories (Stratus Consulting, 2009):

- Recreational opportunities
- Community aesthetics
- Heat stress reductions
- Water quality and aquatic ecosystems
- Wetland creation/enhancement
- Local green jobs
- Energy savings
- Air quality
- Disruptions due to construction

As a result of conducting the study, the city was able to more fairly evaluate the options of traditional versus comprehensive stormwater management to address the city’s long-standing CSO problem. Under the traditional infrastructure alternative, most of these benefits were not accrued, and water quality benefits were limited. Under the 50% LID alternative, which was the alternative ultimately selected by the Philadelphia Water Department, total benefits over a 20-year period added up to $2.8 billion dollars in today’s dollars (more than 20 times the value expected from a 30-foot tunnel option), with some of those benefits expected to be seen in the near future. In addition, the Department concluded that the 50% option would provide more benefits in all three categories than would the development of a 30-foot tunnel (Philadelphia Water Department, 2009).

While in many respects the Philadelphia analysis is much larger than many cities might be able to undertake, the analysis is important not only for the evaluation it provided, but for the underlying information that can be pulled for use in other U.S. cities. For example, it provides a compelling linkage between green infrastructure and improved health, where reductions in heat stress mortality through the mitigation of the urban heat island effect was calculated to provide $1.06 billion in benefits over a 40-year life span through the avoidance of 196 deaths. Similarly, it provides evaluations on the impact of green infrastructure on property values and the ability to increase recreational values. These and other assessments provided within the study serve to increase the collective understanding of the multiple benefits green infrastructure can provide, and one possible way of evaluating them.
CHAPTER 4.0

CONCLUSIONS

4.1 Concluding Remarks

Green infrastructure, along with traditional infrastructure, can play a significant role in addressing a variety of urban water issues with our communities. However, green infrastructure approaches can often be difficult to justify due to a lack of information or understanding of their benefits, or an inability to compare it to traditional approaches using traditional costing methods. Life cycle costs assessments and the triple bottom line approach are two means by which local city and county managers can better weigh the benefits of traditional versus green infrastructure practices over the life of such projects. Other possible methods include benefit cost analyses, damage cost avoided, the productivity method, and the hedonic pricing method (WERF, 2010).

Life cycle cost assessments and the triple bottom line approach seem particularly suited to the evaluation of green infrastructure and traditional techniques due to their ability to incorporate an evaluation of multiple benefits over time. The evaluation of life cycle costs further allows for an evaluation of operation and maintenance costs, which are often lower for green infrastructure practices. Regardless of the approach selected for evaluating different management options, it is important that any decision-making process include a careful review of the financial, social and ecological benefits of selected alternatives. To be practical, however, such processes must also be as simple as possible, allow for flexibility in evaluating both large and small projects, and accommodate the needs of city managers with limited time, expertise, and funds to calculate in-depth analyses (Taylor and Fletcher, 2003).

It is important to note that incorporating such analyses does not guarantee that the most sustainable approach will be selected. There are numerous practical challenges associated with identifying goals and objectives, coordinating amongst traditionally separate departments, and the availability of performance and cost data. There are also limitations in the cost analyses themselves. Determining the appropriate life span can be subjective, and either evaluating incorrect options or incorrectly evaluating the benefits and costs of select options is possible. In spite of such caveats, life cycle cost and triple bottom line assessments are two viable tools for communities to utilize in evaluating and justifying their decisions for stormwater and urban water infrastructure programs.
REFERENCES


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