United States Environmental Protection Agency

Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs

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Cover Photos:
Top Left: Landscaped curb extension captures street runoff (City of San Diego Low Impact Development Design Manual)
Bottom Left: Cisterns at the Pine Knoll Shores Aquarium in Atlantic Beach, NC (Jason Wright, Tetra Tech, Inc.)
Right: Green roof in Philadelphia, PA (U.S. Environmental Protection Agency)

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Alachua County Environmental Protection Division, Gainesville, Florida

Capitol Region Watershed District, St. Paul, Minnesota

Charlotte-Mecklenburg Storm Water Services, City of Charlotte and Mecklenburg County, North Carolina

Kane County, Illinois

City of Kirkland Department Public Works, Washington

City of Lenexa Department of Public Works, Kansas

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Contents

Exhibits

Acronyms and Abbreviations

ACF	Alachua County Forever (Florida)
APSIP	Arlington Pascal Stormwater Improvement Project
APWA	American Public Works Association
BCA	benefit-cost analysis
BES	Bureau of Environmental Services (Portland, OR)
BMP	best management practice
CIP	Capital Improvement Program
CNT	Center for Neighborhood Technology
CRWD	Capitol Region Watershed District (St. Paul area, MN)
CSO	combined sewer overflow
CSSA	combined sewer service area
EPA	U.S. Environmental Protection Agency
GASB 34	Government Accounting Standards Board Statement 34
GI	green infrastructure
GIS	geographic information system
GSI	green stormwater infrastructure
HBA	Homebuilders Association
HOA	homeowners' association
HVAC	heating, ventilation, and air-conditioning
IDED	Iowa Department of Economic Development
LACDPW	Los Angeles County Department of Public Works
LEDC	Lenexa Economic Development Council (City of Lenexa, KS)
LID	low impact development
LID/GI	low impact development and green infrastructure
MARC	Mid-American Regional Council
MMSD	Milwaukee Metropolitan Sewerage District
MODA	multi-objective decision analysis
MS4	Municipal Separate Storm Sewer System
NDS	natural drainage system
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
NRDC	Natural Resources Defense Council
O&M	operation and maintenance

PV	present value
PWD	Philadelphia Water Department
ROW	right-of-way
SPU	Seattle Public Utilities
SSSA	separate sewer service area
SUSTAIN	System for Urban Stormwater Treatment and Analysis Integration
TBL	triple bottom line (in reference to full BCA)
TIF	tax-increment financing
TP	total phosphorus
TSS	total suspended solids
WTP	willingness to pay

1. Introduction

1.1 Objectives

This report was prepared to help utilities, state and municipal agencies, and other stormwater professionals understand the potential benefits of their low impact development (LID) and green infrastructure (GI) programs. The objectives are to highlight different evaluation methods that have been successfully applied, and also to demonstrate cases where LID/GI has been shown to be economically beneficial. The intent of this document is to promote the use of LID/GI, where appropriate, to supplement grey stormwater infrastructure.

To meet this objective, EPA developed 13 case studies of selected public entities throughout the United States that have conducted economic evaluations of their LID/GI programs. Because it is important to look beyond just one measure, such as capital cost, in order to see a complete picture of the economic benefits and costs of LID/GI, a variety of analysis types are presented in the case studies.

EPA selected 13 case studies to represent various types of economic analyses and LID/GI-based programs. The case studies were selected to represent a variety of analysis methods in different geographic areas of the United States, for different types of municipal programs. The case studies highlight locations where LID/GI applications, in combination with grey infrastructure, were found to be economically beneficial. In some cases LID/GI might not be an appropriate choice, but this document should help to enable a more comprehensive assessment.

This document is intended to provide stormwater professionals with useful information and insights to draw upon in their own planning and analysis efforts. It

Low impact development (LID) *is a land development approach that is intended to reduce development related impacts on water resources through the use of stormwater management practices that infiltrate, evapotranspirate, or harvest and use stormwater on the site where it falls.*

Green infrastructure (GI) *for the purposes of this report can be defined as the natural and man-made landscapes and features that can be used to manage runoff. Examples of natural green infrastructure include forests, meadows and floodplains. Examples of man-made green infrastructure include green roofs, rain gardens and rainwater cisterns.*

For the purpose of this report the terms LID and GI are used interchangeably even though landscape architects refer to GI as the network of open space nodes and corridor that provide habitat for wildlife.

The term **grey infrastructure** in this document refers to traditional stormwater management systems that quickly dispose of stormwater, such as pipes, pumps and lined ditches, or use of detention ponds.

is not intended to serve as specific guidance or to provide cost and benefit "rules of thumb" for application to other locations. Nevertheless, many of the approaches and findings of the communities in the case studies are applicable to communities in similar situations.

1.2 Key Findings

Although many entities have begun to implement LID and GI approaches for stormwater management, research shows that a relatively small percentage of jurisdictions have conducted economic analyses of their existing or proposed programs. This lack of program analysis is due to many factors including uncertainties surrounding costs, operation and maintenance (O&M) requirements, budgetary constraints, and difficulties associated with quantifying the benefits provided by LID/GI.

Those entities that have begun to analyze their green infrastructure programs and practices in order to ascertain the cost effectiveness of green infrastructure in comparison to grey infrastructure or hybrid systems have used different types of economic analyses, depending upon their objectives, resources, or other considerations. These analyses ranged in level of complexity, and captured the costs and/or benefits of the programs in different ways. To illustrate this range of analyses, Exhibit 1 presents information on the analytical approaches used by three case study entities. Charlotte-Mecklenburg Storm Water Services conducted a cost-effectiveness analysis to help prioritize its LID/GI alternatives to meet the specific objective of protecting a drinking water reservoir. The Portland Bureau of Environmental Services focused its analysis on a single best management practice (BMP), green roofs, to gain support from developers and building owners. The Philadelphia Water Department (PWD) conducted a benefit-cost analysis (BCA) to compare the benefits and costs of city-wide grey and grey/green stormwater management alternatives. The PWD refer to their study as "triple-bottom-line" (TBL) analysis, a term that has become recognized in municipal asset management to emphasize the financial-social-environmental aspects of a complete benefit-cost analysis, rather than only the financial.

1.3 How to Use This Report

Stormwater professionals can use the information and resources provided in this report when planning, implementing, and assessing their own LID/GI programs. The report provides a starting framework that both illustrates how others have evaluated the costs and benefits of their LID/GI projects and programs and suggests methods communities may want to investigate to get started on their own community-specific analyses.

The main body of the report provides summary information on the types of economic analyses conducted by the case study entities, as well as the key findings and lessons learned by each entity as a result of implementing their green infrastructure programs. The 13 write-ups, which are provided in the appendix, offer more detailed information about each entity's LID/GI program, the role and type of economic analyses conducted, the specific analytical methods used, the results of the analyses, and key challenges and lessons learned. The case studies also provide additional written and Web-based resources related to each case study program.

Exhibit 1. Summary of analytical approaches used by three LID/GI case study agencies

Entity	Charlotte-Mecklenburg Storm Water Services, North Carolina	Bureau of Environmental Services Portland, Oregon	Philadelphia Water Department, Pennsylvania
Program	Stream restoration and BMPs are used to reduce impacts of rapid development on drinking water quality	Ecoroofs program: The City of Portland encourages the construction of green roofs by providing incentives to developers and by requiring green roofs on new city-owned facilities and roof replacement projects.	The Green City Clean Waters Program aims to reduce combined sewer overflows (CSOs) and improve water quality.
Role of economic analysis	BMP project prioritization through evaluation of alternatives	• Determine if benefits exceed cost • If so, use results to increase implementation of ecoroofs in the city	Demonstrate full range of societal benefits of LID/GI to regulators and the public
Type of analysis	Cost-effectiveness	Benefit-cost analysis (BCA; including TBL elements) of hypothetical new commercial building with 40,000-square-foot roof	Benefit-cost analysis (referred to as a TBL analysis by PWD)
Key metrics	Capital cost per pound of sediment prevented from entering stream	• Present value (PV) life-cycle costs • Avoided costs • Environmental and social benefits • Net present value (NPV) of program to the public (e.g., public stormwater system and the environment) • NPV of the program to developers and building owners • NPV to public and private stakeholders combined	• NPV life-cycle costs and benefits of GI and grey approaches • Quantified and monetized social and environmental benefits
Results	• For urban retrofits, stream restoration is the most cost-effective means of controlling sediment deposition into the reservoir. • Prioritization allows the county to implement need-based, rather than opportunity-based, projects	Construction of ecoroofs has: • Immediate and long-term benefits to the public • Positive net benefits accrue to building owners starting in year 20 for the assumed conditions	• LID/GI-based approaches provide important environmental and social benefits that are generally not provided by grey infrastructure • A LID/GI-based approach, coupled with targeted grey infrastructure, is the city's preferred approach to optimize net benefits

Exhibit 2 provides a more comprehensive summary that covers all of the case studies in this report. Exhibit 2 provides a key to help stormwater professionals identify case study entities that have common drivers and program goals and is intended to enable users to quickly identify communities that have begun to address common issues and ascertain how their experiences can be applied to the user's program evaluation process.

The matrix enables users to select case study analyses based on the following factors:

- Objective or role of the economic analysis
- Program goals and objectives
- LID/GI program elements
- Type of economic analysis
- Geographic location
- Urban or rural location
- Population served.

An "**X**" in a cell indicates that the specified characteristic is directly associated with the case entity's economic analysis. An "O" indicates that although the specified characteristic is associated with the case study's LID/GI program, it is not an aspect of the program covered in the economic analysis.

For example, let's say your primary purposes for evaluating your LID/GI program are to prioritize program alternatives and build community support for the preferred alternative indicated by the analysis. You can quickly refer to the Exhibit 2 matrix and identify the case study entities that had similar objectives (i.e., see "Role of Economic Analysis" and "Potential Usefulness of Economic Analysis Results"). If you need to obtain a better understanding of how it may be possible to quantify and monetize the benefits of your program, you will likely want to review the case studies with characteristics similar to your own. For example, if your utility is located in a densely populated urban area where GI will require the retrofitting of existing neighborhoods, it might be helpful to examine the case studies for urban entities.

It is important to note that the focus of this report is not to determine how to identify the most appropriate type of economic analysis. The use of a specific technique or type of analysis depends on a variety of factors. Factors to consider include, the objective of the economic analysis, how you plan to use the results (e.g., to gain stakeholder support, alleviate public concerns, or identify economically feasible solutions) and the budget available for conducting the analysis. On the other hand, the type of LID/GI techniques and the land uses in which they are applied do not seem to play a large role for the type of economic analysis conducted in these case studies. For example, cost-effectiveness and benefit-cost analysis can be applied to LID/GI programs in both rural and urban areas and across a variety of infrastructure types. Consequently, the case study matrix should be used to glean ideas and examples and was not written to serve as a "how-to" manual.

Exhibit 2. Summary of the key characteristics of LID/GI case study entities[a]

Case study characteristics	Alachua County, FL	Capitol Region Watershed District, St. Paul, MN	Charlotte-Mecklenburg County, NC	Kane County, IL	Kirkland, WA	Lenexa, KS	Milwaukee, WI	New York, NY	Philadelphia, PA	Portland, OR	Seattle, WA	Sun Valley, Los Angeles, CA	West Union, IA
Role of economic analysis													
Develop project options/strategies (5)					X		X	X			X	X	
Prioritize projects (5)			X		X		X	X			X		
Evaluate cost-effectiveness (5)		X	X				X	X			X		
Demonstrate benefits (8)	X			X	X	X	X		X		X	X	
Potential Usefulness of Economic Analysis Results													
Inform future project development/selection (7)		X	X		X		X	X	X			X	
Gain support for project (9)	X			X	X	X	X		X	X		X	X
Obtain funding for LID/GI approach(2)												X	X
Bring in outside partners (2)					X							X	
Increase implementation of program activities (1)										X			
Establish basis for program adoption/continuation (4)				X		X				X			X
Stated program goals/objectives													
Meet Municipal Separate Storm Sewer System (MS4) requirements/separate sewer concerns (4)					X		X			X	X		
Reduce CSOs (5)							X	X	X	X	X		
Reduce stormwater runoff (9)		X	X	X	X		X	X	X	X	X		
Flood control (7)				X		X	○			X	X	X	X
Improve water quality (13)	X	X	X	X	X	X	X	X	X	X	X	X	X
Improve drinking water quality (1)			X										

Case study characteristics	Alachua County, FL	Capitol Region Watershed District, St. Paul, MN	Charlotte-Mecklenburg County, NC	Kane County, IL	Kirkland, WA	Lenexa, KS	Milwaukee, WI	New York, NY	Philadelphia, PA	Portland, OR	Seattle, WA	Sun Valley, Los Angeles, CA	West Union, IA
Reduce erosion (4)			X	X					X	X			
Improve/protect habitats (11)	X		X	X	X	X	X		X	X	X	X	X
Recharge groundwater (2)							X					X	
Provide/enhance recreational opportunities (9)	X	X		X	X	X	X	X	X			X	
Provide/enhance aesthetics/quality of life (6)	X			X	X		X		X			X	
Provide other environmental benefits (6)	X						X		X	X	X	X	
Replace aging infrastructure (1)													X
Reduce impacts from growth/development (6)	X	X	X	X	X	X							
Enhance citizen safety (2)					X								X
Increase multiple agency participation (2)					X							X	
Program elements													
LID/GI standards/ordinances/guidelines (6)	○		X	X		X		○			X		
Fees and economic incentives (5)						X		○	○	○	X		
Large-scale bioretention ponds (3)	○	X				○							
Land acquisition/preserve open space (6)	X			X		○	○			○		X	
Stream restoration (3)			○			○			X				
Reforestation/tree planting/urban forestry (5)			○					X	X	○		X	
Floodplain reconnection (1)			○						X				
Wetland development (4)						○		○	X			X	
Underground infiltration trenches/storage (3)	○	X										X	
Green streets and alleys (10)	○				X	○	X	X	X	○	X	X	X
Permeable pavements (7)	○			○	X		X	X	X		X		

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Smaller-scale bioretention and infiltration (13)	○	X	X	X	X	X	X	X	X	○	X	X	X
Ecoroofs and blue roofs (6)				○			X	X	X	X	○		
Impervious area reduction (3)				X	X						X		
Rainwater harvesting (7)	X			○			○	X		○	○	X	
Type of economic analysis													
Capital cost assessment (1)						X							
Life-cycle cost analysis (1)													X
Cost-effectiveness (5)		X	X				X	X			X		
Fiscal impact analysis (1)				X									
Benefit valuation (2)							X						X
Quantitative ranking of BCA costs/benefits (1)					X								
Benefit cost analysis (3)	X									X		X	
BCA analysis (or TBL analysis) (4)							X		X	X		X	
Geographic location													
Northeast (1)								X					
Mid-Atlantic (1)									X				
Midwest (5)		X		X		X	X						X
South (2)	X		X										
West (4)					X					X	X	X	
Urban/rural													
Urban (11)	X	X	X	X	X		X	X	X	X	X	X	
Rural (2)						X							X

Case study characteristics	Alachua County, FL	Capitol Region Watershed District, St. Paul, MN	Charlotte-Mecklenburg County, NC	Kane County, IL	Kirkland, WA	Lenexa, KS	Milwaukee, WI	New York, NY	Philadelphia, PA	Portland, OR	Seattle, WA	Sun Valley, Los Angeles, CA	West Union, IA
Population served													
Large (> 1 million) (3)							X	X	X				
Medium/Large (200,000–999,999) (6)	X	X	X	X						X	X		
Medium/Small (10,000–199,999) (3)					X	X						X	
Small (< 10,000) (1)													X

a. Cells marked with an "**X**" indicate that the specified program goal/objective or program element is directly associated with the case entity's economic analysis. The "O" indicates that the specified program goal/objective or program element is associated with case study's LID/GI program, not the aspect of the program covered in the economic analysis.

2. Background

Managing stormwater runoff solely through traditional "grey" infrastructure systems can present a variety of challenges, including high construction, maintenance, and repair costs; increasing combined sewer overflow events; and the introduction of pollutants into source waters. These problems are increased as population and development continue to increase and new challenges, such as changing weather patterns, increasing energy costs, new environmental concerns, and aging water infrastructure arise. As the complexity and magnitude of these issues increase, states, cities, and water resource managers increasingly have recognized that a new, integrated approach to stormwater management—one that focuses on sustainability and benefits for multiple stakeholders—will be needed to help ensure that the nation can provide the quality and quantity of water demanded in the future.

Exhibit 3. Examples of the potential environmental, financial, and social benefits of LID/GI

- Environmental benefits
  - Improved water quality
  - Improved air quality from trees
  - Improved ground water recharge
  - Energy savings from reduced air conditioning
  - Reduced greenhouse gas emissions
  - Reduced urban heat stress
  - Reduced sewer overflow
- Financial benefits
  - Reduced construction costs compared with all-grey infrastructure, or compared with upsizing grey infrastructure for increased runoff
- Other social benefits
  - Improved aesthetics
  - More urban greenways
  - Increased public education on their role in stormwater management
  - Reduced flash flooding
  - Green jobs
  - Potential increase in economic development from improved aesthetics

The use of LID/GI can result in a number of financial, environmental, and social benefits, as illustrated in Exhibit 3. Communities throughout the United States are beginning to recognize these benefits and have become increasingly interested in implementing LID/GI-based approaches. However, because LID and GI have not yet been implemented on a wide scale, a number of uncertainties surround the implementation of these approaches in comparison with traditional or grey infrastructure. Adoption of LID/GI practices has been hindered by concerns that implementing LID/GI programs will increase costs or not adequately protect property or the environment. Findings from the case studies related to these concerns include the following:

- *Perception: It is difficult to develop estimates for the capital costs and O&M costs associated with LID/GI-based technologies because of the site-specific nature of LID/GI, which is often based on soil, vegetation and other unique site factors.* Some case study

entities used pilot studies, developed locally focused design guides, and obtained assistance from consultants or university extension services to adapt O&M techniques to their areas and develop and track the costs of these techniques. Many case study entities successfully estimated the capital costs of their LID programs and projects using similar approaches.

- *Perception: There is uncertainty regarding the effectiveness of LID/GI approaches compared to traditional infrastructure, especially over the long term.* As with estimating maintenance needs, communities have initiated pilots to gain a comfort level with using LID practices. By monitoring pilot- and full-scale installations, in addition to reviewing available literature, entities can inform their expectations concerning the effectiveness and the limitations of these practices.
- *Perception: The up-front capital costs associated with LID/GI are often more than those associated with traditional infrastructure.* In some cases, entities found the capital costs required for LID/GI approaches, or mixed green/grey approaches, to be less than the capital costs required for traditional grey infrastructure. Furthermore, when life-cycle costs (including capital, O&M, and replacement costs over time) are taken into account, cost savings compared to traditional infrastructure can be even more significant. In addition, communities are finding that even when the capital costs are higher—for example, in urban areas with no land available for infiltration—the associated benefits that accrue from the implementation of LID/GI practices often provide the value to justify adoption of these practices. For example, Charlotte-Mecklenburg Water Services found that reforestation was not the most "cost-effective" stormwater management alternative, but it was implemented for the many benefits an urban forest provides in addition to stormwater management, e.g., aesthetics, shading and air pollution abatement.
- *Perception: The monetization of environmental and social benefits is a relatively new field, with few standardized approaches.* Some communities have turned to simply listing the benefits and assigning qualitative or quantitative rankings to establish an acknowledgment of the value of the societal or environmental benefits associated with LID/GI. Although estimating the monetary value of environmental or other social benefits can be difficult, some communities are beginning to use well-established methods or emerging tools for monetizing certain benefits (e.g., reduction in pollutant levels, increased property values, using benefit calculators such as the U.S. Department of Agriculture Forest Service's i-Tree program [www.itreetools.org]).

This report provides examples of methods for evaluating the potential economic benefits of LID/GI and attempts to address some of the concerns that the uncertainties of benefit analyses are too complex to undertake. As development pressures increase and aging infrastructure needs to be replaced or new infrastructure added, it is essential that agencies, utilities, and municipalities begin to develop the capability to use the appropriate tools and analytical framework to assess, compare and evaluate the various alternatives, both green and grey, to determine the best solution for that community.

3. Approach

To compile the case studies in this report, more than 45 communities with existing or planned LID/GI-based programs were evaluated. The communities included in this review were identified by web searches, information from recognized LID/GI sources, e.g., the U.S. Environmental Protection Agency (EPA) GI and LID websites, interviews with EPA representatives from each of the 10 EPA regions, and the research team's personal knowledge and experience.

The 13 case study communities in Exhibit 4 were selected to represent various types of economic analyses and LID/GI programs, as well as a broad geographic and demographic range.

The case studies were developed from interviews with a representative from each case study community, as well as reports and data provided by each entity. Each case study contains highlights of the community's LID/GI program; a description of the economic analysis that was conducted; the methods, results, and outcomes of the economic analysis; and key lessons learned. Examples of similar LID/GI programs and economic analyses, sources, and contacts are also provided. More detailed case study information for each community is provided in the appendix.

Exhibit 4. LID/GI case study communities

1. **California:** Sun Valley Watershed, Los Angeles County Department of Public Works (LACDPW)
2. **Florida:** Alachua County Environmental Protection Department and Public Works Department
3. **Illinois:** Kane County Facilities, Development, and Environmental Resources Department
4. **Iowa:** City of West Union and the Iowa Department of Economic Development (IDED)
5. **Kansas:** City of Lenexa Public Works Department, Watershed Division
6. **Minnesota:** Capitol Region Watershed District, St. Paul
7. **New York:** Mayor's Office of Long-term Planning and Sustainability, New York City
8. **North Carolina:** Charlotte-Mecklenburg Storm Water Services, Mecklenburg County, City of Charlotte
9. **Oregon:** Portland Bureau of Environmental Services (BES)
10. **Pennsylvania:** Philadelphia Water Department
11. **Washington:** The City of Kirkland Public Works Department
12. **Washington:** Seattle Public Utilities (SPU)
13. **Wisconsin:** Milwaukee Metropolitan Sewerage District (MMSD)

4. Overview of Case Study LID/GI Programs

The LID/GI projects and programs implemented by the case study entities vary significantly. Exhibit 5 summarizes factors influencing the implementation of specific LID/GI practices based on program needs and objectives.

Exhibit 5. Primary case study LID/GI program objectives

- Meet EPA National Pollutant Discharge Elimination System (NPDES) permit for either combined sewers, sanitary sewer overflows, or separate storm sewer systems.
- Reduce combined sewer overflows (CSOs) to comply with consent decrees.
- Reduce stormwater runoff and related pollutants.
- Reduce localized flooding during small storm events.
- Improve water quality in lakes, rivers, and streams.
- Improve drinking water quality.
- Reduce erosion and resulting property damage.
- Protect aquatic habitats.
- Increase infiltration to recharge ground water for water supply and maintenance of stream baseflow.
- Provide recreational opportunities and increased public access to local water bodies.
- Enhance aesthetics and quality of life.
- Provide other environmental benefits.
- Reduce cost of replacing aging infrastructure.
- Reduce adverse impacts from growth and development.

A brief overview of each entity's LID/GI program is presented below. Each overview includes the name of the case study and a description of the program objectives, components, and economic analysis. Exhibit 6 summarizes the types of program elements implemented by the case study entities. The economic analyses conducted by each case study entity are explored in more detail in Section 5 which covers the Economic Analyses of LID/GI Programs.

Exhibit 6. Case study LID/GI program elements

- LID development standards/ordinances/guidelines
  - Stream setbacks
  - Protection of priority natural resource areas
  - Zoning requirements
  - Design guidelines
- Fees and economic incentives
  - Drainage fees
  - Systems development fees
  - Green roof incentives
- Large-scale bioretention areas (e.g., retention ponds)
- Land acquisition
- Open space preservation and park development
- Stream restoration
- Reforestation/tree planting/urban forestry
- Floodplain reconnection
- Wetlands development
- Underground infiltration trenches/storage
- Green streets and alleys
- Permeable pavement for streets, sidewalks, and parking areas
- Smaller-scale bioretention and infiltration
  - Rain gardens
  - Bioretention/bioinfiltration areas
  - Bioswales
  - Filter strips
  - Depressional parking islands and road medians
- Ecoroofs/green roofs
- Blue roofs
- Reduction of impervious surfaces
- Rainwater harvesting
  - Rain barrels
  - Cisterns
  - Disconnecting downspouts

Evaluating the Benefits of Green Infrastructure to Reduce Localized Flooding
(Sun Valley Watershed, Los Angeles County Department of Public Works, Los Angeles County (LACDPW), California)

LACDPW developed a comprehensive LID-based program that offers a multipurpose approach to stormwater management in the Sun Valley watershed. The program, which was initiated with an extensive set of infiltration-based projects, was initially undertaken to respond to localized flooding. It developed into a plan to integrate flood control, stormwater pollution reduction, and water conservation efforts using infiltration and stormwater recycling practices. The program also addresses other community needs, such as improving recreational resources and wildlife habitat, and enhancing aesthetic amenities in the watershed. Projects include large scale infiltration basins such as the Sun Valley Park Project, constructed wetlands, tree plantings, development of parks and open space, and storm drains systems designed to convey stormwater to the project areas. The LACDPW conducted a benefit-cost analysis (BCA) that compared the capital, land, and O&M costs with the environmental and social benefits of its stormwater management alternatives. The results led the Department to select an integrated solution.

Preserving Suburban Lands to Improve Water Quality Provides a Good Return on Investment for the Community
(Alachua County Environmental Protection Department and Public Works Department, Alachua County, Florida)

Alachua County which is located within the Gainesville, FL metropolitan area, developed its LID/GI-based program to help mitigate the impacts of historical land development and prepare for the expected population and development growth related impacts on water resources in the region. The county's program includes development standards that require GI and incentives for the use of GI on private lands. The Alachua County Forever (ACF) program is the keystone of the program. Through ACF, the county acquires, protects, and manages environmentally significant lands in order to protect water resources, wildlife habitat, and natural areas suitable for resource-based recreation. Alachua County conducted a benefit-cost analysis (BCA) that compared the benefit of increased property values that resulted from increases in open space against the decreased tax revenues lost from public acquisition of private property under the management of the ACF program.

Finding that Environmentally Sensitive Land Development is also Fiscally Responsible
(Kane County, Illinois, Blackberry Creek Watershed)

Kane County, located just west of Chicago, initiated a number of programs to encourage "conservation-based land development." Its goal was to reduce flooding and streambank erosion, improve water quality, and enhance aquatic habitat in local streams and wetlands. A key component of the county's program is adoption of an LID/GI county stormwater ordinance (which applies to all new development within the county) and corresponding LID/GI-based BMPs. The BMPs include a number of green stormwater infrastructure (GSI) management practices, as well as site planning and development design approaches that preserve existing natural areas and use naturalized drainage, retention of small storm events, and detention for larger storms. The county successfully implemented several naturalized detention basin and permeable pavement projects, narrow street designs, demonstration projects at a local school, and cluster development. It conducted a fiscal impact analysis of county revenues and expenditures under both conservation-based and conventional alternatives.

Long-Term Cost Savings Plus Environmental and Social Benefits Envisioned in Rural Green Streets Pilot Project
(West Union, Iowa)

In partnership with the Iowa Department of Economic Development, West Union developed an integrated approach to community sustainability and livability through the Iowa Green Streets Pilot Project, which includes incorporating LID/GI techniques into the renovation of six downtown blocks. Primary objectives of the project include improving citizen safety, replacing aging infrastructure, improving water quality and habitat in a nearby trout stream, and reducing flooding in the downtown area. As part of the project analysis, West Union compared the long-term ownership costs of a green street design with those of a conventional design.

Demonstrating Cost Savings Associated with New LID/GI Development Standards
(Public Works Department, City of Lenexa, Kansas)

The objectives of Lenexa's LID-based program, Rain to Recreation, are (1) to reduce flooding, (2) to improve water quality and habitat, and (3) to provide recreational opportunities. The program consists of regulatory and non-regulatory approaches to stormwater management. The non-regulatory measures include major capital projects (e.g., lakes that serve as regional retention facilities), land acquisition, and stream restoration projects, as well as GI-based components such as green street improvements, rain gardens, bioretention areas, and wetlands. The regulatory measures include LID-oriented development standards for new development and an accompanying BMP manual, protection of priority natural resource areas, and a stream setback ordinance. Lenexa conducted a capital cost assessment that compared the capital costs of implementing LID BMPs with the costs of traditional approaches for different types of development.

Realizing Cost Savings and Environmental Benefits by Using Green Stormwater Infrastructure Retrofits
(Capitol Region Watershed District, Minnesota)

The highly developed nature of the Capitol Region Watershed District's (CRWD's) service area leaves little flexibility for stormwater management. When CRWD evaluates BMPs, it is primarily concerned with identifying areas to retrofit. Through its Arlington Pascal Stormwater Improvement Project (APSIP), CRWD implemented LID techniques to reduce localized flooding and improve water quality by reducing the amount of phosphorus, bacteria, mercury, nutrients, polychlorinated biphenyls, and turbidity discharging into an important recreational lake and the Mississippi River. APSIP consists of 18 LID-based stormwater BMPs, including eight rain gardens, eight underground (under-street) infiltration trenches, a large underground infiltration/storage facility, and a regional stormwater pond, all in a 298-acre subwatershed. CRWD investigated the capital cost and cost-effectiveness of different BMPs in terms of pollutant removal and flood control.

Bringing Together Agency Stakeholders to Assess the Cost-Effectiveness and Feasibility of Sustainable Stormwater Management in Combined Sewer Overflow Areas
(Mayor's Office of Long-term Planning and Sustainability, New York City, New York)

New York City developed a sustainable stormwater management plan as part of the city's broader sustainability initiative, PlaNYC. The overall water quality goal of PlaNYC is to improve public access to (and recreational use of) the city's tributaries from 48 percent today to 90 percent by 2030. Toward this end, the plan evaluates the feasibility of various policies that, when fully implemented, will create a network of decentralized source controls to detain or capture more than one billion additional gallons of stormwater annually. The plan includes a variety of structural and nonstructural source control measures related to four program areas: the public right-of-way, city-owned property, open space, and private development. Structural source control measures include green roofs, blue roofs, rainwater harvesting, vegetated controls, tree planting, permeable pavements, and engineered wetlands. Nonstructural measures include design guidelines, performance measures, zoning requirements, and economic incentives. The city conducted a cost-effectiveness analysis comparing various LID runoff control options with traditional grey infrastructure options.

Using Cost-Effectiveness to Prioritize Projects that Reduce the Impacts of Rapid Development that Impair a Drinking Water Reservoir
(Charlotte-Mecklenburg Storm Water Services, City of Charlotte and Mecklenburg County, North Carolina)

The primary objective of Charlotte-Mecklenburg Storm Water Services' stormwater program is to protect drinking water quality and water quality for recreation, aquatic habitat, and endangered species. The biggest threat to water quality in the region is an increased volume of stormwater runoff caused by rapid development; the runoff contributes pollutants and sediment from stream erosion. The LID-related components of the county's capital improvement program (CIP) include three focus areas: in-stream restoration, upland LID-based retrofits (e.g., rain gardens, bioswales), and reforestation. In addition, the Town of Huntersville (in Mecklenburg County) implemented a post-construction LID-based ordinance to mitigate degradation of the drinking water reservoir from future development. The county's incorporation of LID approaches was initiated based on watershed modeling that had compared the effectiveness of alternative stormwater management approaches with existing (traditional) practices at build-out conditions. The model results indicated that LID was the only approach that would achieve sufficient pollutant removal and prevent further degradation of the county's waterways. Today, LID is being implemented in combination with conventional approaches designed to manage larger storms.

A Benefit-Cost Analysis Provides the Basis for Incentivizing Ecoroof Construction
(Bureau of Environmental Services, Portland (BES), Oregon)

BES developed a stormwater management program that recognizes the need for sustainable stormwater management systems throughout the city. The LID-based program helps the city comply with its MS4 discharge permit, reduce CSO events, maintain water quality, and control flooding. Specific program components include green roofs, green streets, stormwater BMP monitoring, school BMPs, and a financing program. BES conducted a BCA (including social, financial, and environmental elements) of a hypothetical green roof, calculating the net present value (NPV) of the practices to illustrate the long-term value of these investments to the public, developers, and building owners.

A Benefit-Cost Analysis of Combined Sewer Overflow Control Options
(Philadelphia Water Department (PWD), Philadelphia, Pennsylvania)

PWD is committed to the development of a balanced "Land-Water-Infrastructure" approach to achieve its watershed management and CSO control goals. The PWD program includes traditional grey infrastructure, as well as land-based LID/GI stormwater management techniques and projects involving the physical reconstruction of aquatic habitats. The LID/GI land-based approaches include disconnection of impervious cover, bioretention, subsurface storage and infiltration, green roofs, swales, green streets (including permeable pavement), and tree canopy. The water-based approaches include streambed and bank stabilization and reconstruction, aquatic habitat creation, plunge pool removal, improvement of fish passage, and floodplain reconnection. The PWD conducted a BCA analysis that demonstrated the full range of costs and social benefits of LID/GI to regulators and the public. The PWD uses the term "Triple-Bottom-Line," a recently

adopted term used in municipal asset management to emphasize that a BCA includes social and environmental considerations, as well as financial elements.

Ranking Benefits to Help Assess the Feasibility of LID Approaches in Capital Improvement Program (CIP) Transportation Projects
(The City of Kirkland Public Works Department, Kirkland, Washington)

In 2007 stormwater engineering staff in the Kirkland Public Works Department began investigating ways to integrate LID/GI into CIP transportation projects. Primary drivers included the protection of Puget Sound and local waterways and the anticipation of future NPDES MS4 permit requirements for LID/GI. In addition, analyses conducted in surrounding municipalities showed that it was often more cost-effective to implement LID/GI than more traditional approaches such as pipes and ponds. To identify implementation opportunities, Kirkland stormwater staff evaluated the feasibility of integrating LID/GI elements into 10 planned CIP projects. This evaluation helped them to establish a process for integrating LID into CIP projects. Today, when technically feasible, LID is integrated into the conceptual design phase of all projects involving public right-of-ways.

Using an Asset Management Approach for Optimizing Green Stormwater Infrastructure (GSI) Application
(Seattle Public Utilities (SPU), Seattle, Washington)

SPU became a leader in municipal water and wastewater asset management beginning in 2002 and applied these techniques to its advanced GSI program. The primary environmental concerns facing SPU's drainage and sewer department include impairment of Seattle's receiving waters and aquatic life and flooding of roadways and property due to increasing runoff. SPU developed a comprehensive GSI program to address stormwater management throughout the city. The program includes natural drainage system (NDS) projects, which involve redesigning residential streets to take advantage of plants, trees, and soils to clean runoff and manage stormwater flows; GSI for stormwater code compliance; and Residential Rainwise, a public education and outreach program which was designed to encourage residential customers to take steps to reduce the volume of stormwater sent to public conveyance systems from private properties. SPU's asset management process allows the utility to make decisions in a transparent manner, fully informed by life cycle analyses and, where possible, BCA. SPU uses the term TBL in its asset management program for costs and benefits analyses to highlight that a BCA includes social, environmental, and financial considerations. The SPU case study describes a business case study of one of its NDS projects, which was presented for asset management review.

Optimizing the Potential for Green Infrastructure to Reduce Overflows and Provide Multiple Benefits
(Milwaukee Metropolitan Sewerage District (MMSD), Milwaukee, Wisconsin)

LID/GI solutions are critical components of MMSD's plan to prevent water quality degradation and flooding that can result from development and reduce CSOs. MMSD's programs include Green Seams, which involves purchasing and preserving large areas of

land (that contain water-absorbing [hydric] soils) along waterways, and a very successful rain barrel program. In addition, MMSD implemented several LID/GI demonstration projects on both private and public lands. Going forward, the district will focus on implementation of various LID/GI strategies such as the integration of LID/GI approaches into its 2020 facilities planning effort. MMSD envisions that subsequent analyses will help to further optimize the integration of LID/GI into its 2035 or 2040 facilities plans.

5. Economic Analyses of LID/GI Programs

Utilities and other implementing agencies are using numerous economic analysis techniques to evaluate stormwater management alternatives. The following sections describe eight types of economic analyses represented in the 13 case studies (Section 5.1); the benefits and costs evaluated by the case study entities (Section 5.2); and a summary of each case study's economic analysis, including the role and type of analysis used, key metrics, and outcomes (Section 5.3).

5.1 Types of Economic Analyses

Exhibit 7 lists the seven types economic analyses represented in the case studies and provides examples of the key components of each analysis. More detailed descriptions are provided below in the approximate order of complexity. The level of complexity increases as more metrics, e.g., capital costs, life-cycle costs, benefits and analytical methods, e.g., life-cycle costing, NPV, monetizing benefits are included in the analysis.

Capital cost assessment. The simplest form of economic analysis, capital cost assessment can be used to compare the up-front costs associated with both LID/GI and grey infrastructure alternatives. Capital costs typically include costs incurred for the purchase of land, construction, materials, and equipment used in the development of stormwater infrastructure, i.e., the total cost of bringing a project to an operable status. Capital cost assessment does not incorporate O&M or life-cycle costs and therefore does not always provide an appropriate comparison of alternatives when the owner has a long-term financial interest. Unlike operating costs, capital costs are one-time expenses, although payment can be spread out over many years in financial reports and tax returns. The City of Lenexa, Kansas, used capital cost assessment to show savings associated with LID/GI BMPs compared with traditional techniques.

Benefit-cost analysis. BCA is a common accounting framework used to evaluate the net effect of a proposed program or project. Questions are posed such as: Do the benefits outweigh the costs? Who benefits? Who incurs the costs?[1] A BCA can be used to determine whether a proposed project/program is a sound investment and used to determine how the costs and benefits compare to other options. This type of assessment can include aspects such as avoided costs or opportunity costs associated with the capital construction decision.

Alachua County, Florida, conducted a BCA of its LID/GI open space preservation program in response to public concern over potential loss in property tax revenue associated with acquiring open space for preservation. The county compared the cost of the reduction in property taxes from the acquisition of open space against the benefits of increased property values and

[1] Note that BCA is different from cost-effectiveness analysis. Cost-effectiveness analysis is used to determine capital costs or life-cycle costs per unit of a single parameter, e.g., the cost per pound of pollutant removed, whereas BCA is used to compare all monetized benefits to costs to derive an estimate of net monetized benefits (or a benefit-cost ratio). A BCA should also qualitatively describe non-quantifiable benefits and costs.

Exhibit 7. Economic analyses used by case study entities

Type of economic analysis	Components of economic analysis
Capital cost assessment	• Up-front costs, e.g., land, construction, materials, equipment • One-time expenses (does not include O&M or financing costs)
Benefit-cost analysis (BCA)	• Comparison of financial or monetized benefits to costs (NPV life-cycle benefits and costs if possible) • Quantified and monetized financial, environmental, and social costs and benefits (sometimes called "triple-bottom-line" in municipal asset management programs) • Qualitative description of financial, environmental, and social benefits (and costs) when quantification is not feasible
Life-cycle cost and/or benefit assessment component of BCA	• Life-cycle costs over the project life (sum of PV of investment costs, capital costs, installation costs, O&M costs, replacement costs, and disposal costs over project or program lifetime) • Life-cycle benefits over the project life (sum of PV of benefits over project or program lifetime) • Life-cycle net benefits ,i.e., NPV
Cost-effectiveness analysis	• Capital or life-cycle costs as measured over comparative and uniform time frame, e.g., the cost per pound of a specific pollutant removed per year
Fiscal impact analysis	• Impact of development or land use change on the costs of governmental units or services • Impact of development or land use change on revenues of governmental units
Benefit valuation component of BCA	• Quantification of benefits in non-monetary terms, e.g., pounds of pollutant removed, number of increased recreation visitor days • Monetization of benefits, e.g., avoided treatment costs, monetary value of recreational user days
Quantitative ranking informed by qualitative description of non-monetized benefits and external costs	• Qualitative description of benefits and costs • Quantitative ranking of benefits and costs, e.g., on a scale of 1 to 5

subsequent increased assessments for those properties located near the newly acquired open-space areas.

Traditionally, BCAs have included benefits and costs that can easily be assigned a market value, e.g., revenues and expenditures. BCAs using approaches that take into account the environmental and social values associated with proposed programs in addition to the financial outcomes are becoming more common. (To emphasize that an analysis does include social and environmental considerations, as well as financial, some municipalities, including Seattle and Philadelphia, have used the term triple-bottom-line (TBL) to refer to a comprehensive BCA.)

The comprehensive BCA approach reflects the fact that society and its enterprises—including the institutions that work specifically in the public interest, such as water and wastewater utilities—typically are engaged in activities intended to provide the greatest total value to the

communities they serve. These values extend beyond the traditional financial bottom line of a standard financial analysis, which portrays only cash flows. Agencies that serve the public interest also need to consider other responsibilities that do not directly show up in the financial bottom line such as reducing urban heat stress and reducing risk to public safety associated with localized flooding. Optimal program design thus accrues benefits across programs by identifying and measuring how any one action or set of actions contributes to "social," "environmental" and "fiscal" bottom lines.

A comprehensive BCA assesses the full range of internal and external costs and benefits of an activity project or program, including nonmarket outcomes. It provides an organizing framework within which the broad array of benefits and costs can be portrayed and communicated.

A BCA should include outcomes that can be quantified into physical units such as reduced tons of carbon or increased recreational days, or monetized into dollar terms. The analyses should also be conducted to include, as much as possible, outcomes that are less amenable to reliable valuation and instead require qualitative discussion. To assign monetary values to social and environmental outcomes, economists typically use surveys, inferences from market behavior, or other modeling techniques.

The Los Angeles County Department of Public Works, the Portland Bureau of Environmental Services, the Philadelphia Water Department, and the City of Kirkland, Washington, all include comprehensive BCA components in their economic analyses, taking into account at least some social and environmental costs and benefits associated with their respective programs and projects. As described in the case studies, not all entities were able to quantify and/or monetize benefits, and the level and depth of analyses varied across studies. For example, Portland BES monetized several environmental benefits that are not typically valued in traditional BCAs, i.e., the value of habitat creation and improved air quality. PWD quantified and monetized benefits and costs across social, environmental, and financial lines, developing a comprehensive BCA of proposed LID/GI program options.

Life-cycle cost or benefits assessment component of BCA. In economics, life-cycle costs are defined as the sum of the present value (PV) of investment costs, capital costs, installation costs, O&M costs, and replacement and disposal costs over the life of a project.[2] Similarly, life-cycle benefits represent the PV of the benefits of a project that accrue over its life. A comprehensive BCA will include calculation of life-cycle net benefits, also referred to as the net present value (NPV) of a project, which are the PV benefits minus PV costs. For a rural green street project, West Union calculated the life-cycle cost savings associated with the use of permeable pavement compared to the costs associated with using traditional pavement. The analysis showed that although the permeable pavement would cost more up front, the city would realize savings beginning in year 15 of the project due to reduced O&M costs compared with the cost of deicing traditional pavement.

Life-cycle costs and benefits often serve as the basis for cost-effectiveness and benefit-cost analyses (described below). For example, Seattle Public Utilities (SPU) used life-cycle costs to conduct cost-effectiveness analysis of NDS project options. The results yielded life-cycle costs per gallon of stormwater infiltrated, per greened acre, and per kilogram of total suspended solids (TSS) removed. SPU considers its natural drainage infrastructure which includes the raingardens,

bioswales and green roofs it builds and maintains as part of its overall infrastructure and reports this infrastructure on its basic financial statements in adherence to the Government Accounting Standards Board Statement 34 (GASB 34) requirements for state and local governments. It capitalizes its GSI assets in the same way as accounts for its traditional infrastructure, based on the useful life of the asset and the typical replacement cycle. By reporting its GSI infrastructure under GASB 34, SPU can show an increased value of its assets and equity, thereby supporting its ability to fund expenditures from the capital budget. Reporting under GASB 34 also enables SPU to capture the value of these GI assets in its financial reporting and makes the economic benefits of GI more explicit when planning for future expenditures.

The Philadelphia Water Department's (PWD) BCA analysis of green and grey infrastructure alternatives included an assessment of life-cycle benefits over a 40-year period. As part of this analysis, PWD evaluated the city-wide benefits of specific GI practices, taking into account planned implementation schedules over the life of the project, as well as the maturation of GI components. For example, a tree will not provide as many benefits (such as shading and particulate interception and retention) the year it is planted as it will 20 years later, when it is fully mature.

Cost-effectiveness analysis. Communities can use cost-effectiveness analysis to more directly compare LID/GI and grey infrastructure solutions. This type of analysis is used to determine and compare the capital costs or life-cycle costs per unit of a specific measure, e.g., stormwater runoff reduction, pounds of pollutant removed. The Capitol Region Watershed District (CRWD) in the St. Paul, Minnesota, area used cost-effectiveness analysis to determine the PV cost per cubic foot of stormwater reduction associated with different LID/GI -based BMPs. CRWD also determined the PV cost per pound of pollutant removal achieved. Mecklenburg County, New York City, SPU, and MMSD also conducted cost-effectiveness analyses as part of their economic evaluations of LID/GI.

Fiscal impact analysis. Fiscal impact analysis is used to estimate the impact of a development or a land use change on the costs and revenues of governmental units. The analysis is generally based on a community's fiscal characteristics, e.g., revenues, expenditures, land values and characteristics of the development or land use change, e.g., type of land use, distance from central facilities. The analysis enables local governments to estimate the difference between the costs of providing services to a new development and the revenues—taxes and user fees, for example—that will be generated by the development. Kane County, Illinois, used fiscal impact analysis to compare the public costs (net revenues/costs) associated with LID/GI-based development against the costs of traditional development practices.

Benefit valuation component of BCA. Several case study entities were interested in quantifying the benefits provided by various alternatives or projects over time and did not necessarily need to compare the benefits with program costs. Milwaukee's Metropolitan Sewerage District (MMSD) evaluated the benefits (see below) of applying LID/GI practices throughout the city's combined sewer service area. The benefits identified include increased property values, job creation, reduced infrastructure costs, reduced pumping costs, increased recreational opportunities, reduced stormwater volume and sediment loading, increased groundwater recharge, increased carbon sequestration, and reduced energy use. MMSD believes that this analysis will help

MMSD employees, regulators, and the public to understand the multiple benefits of GI and move it forward.

Quantitative ranking of a full range of benefits and costs. The first step in a BCA is to determine an expected effect, such as a quantitative ranking, then design a study plan to monetize the expected costs and benefits. Due to a number of factors such as limited resources and insufficient data, it is not always feasible to quantify or monetize the benefits and costs associated with a given project or program. In such cases, communities can qualitatively describe the full range of benefits and costs and then conduct a quantitative analysis of the costs and benefits based on a numeric scale that represents low to high, e.g., a scale of 1 to 5. Cost and benefit categories also can be assigned a weighting factor based on individual agency objectives. Using weighting factors allows the community to establish a framework for prioritizing/ranking proposed program options. Kirkland, Washington, used this approach to evaluate the integration of LID/GI practices into CIP transportation projects. As a result, the county established a process for including LID/GI in all CIP transportation projects.

5.2 Metrics for Costs and Benefits Analyzed by Case Study Entities

Exhibit 8 shows the various cost and benefit metrics quantified and/or monetized by the case study entities. Benefits and costs that were qualitatively discussed are not included in Exhibit 8.

Exhibit 8. Summary of cost and benefit metrics used by case study entities

Cost-related metrics	Benefits metrics
Total costs can be presented in a number of ways: • Capital costs • O&M costs • Life-cycle costs • Annualized costs • Cost per unit of stormwater volume reduction or infiltration • Cost per pound of total phosphorus, total nitrogen, and/or TSS removed • Cost per unit of peak flow reduction • Cost per greened acre • Cost of LID/GI techniques compared to grey or traditional approaches • Net public costs of LID-based development (costs minus revenues) • Cost of construction disruption based on amount of extra time local residents will spend in construction-related traffic	• Avoided localized flood control facility costs • Avoided water quality treatment costs • Avoided grey infrastructure costs • Avoided social costs due to creation of “green” jobs • Energy savings due to reduced need for heating and cooling, and associated value • Reduced carbon dioxide emissions due to energy savings and carbon sequestration, and associated value • Change in property values • Avoided health costs due to improved air quality • Value of habitat provided by green roofs, based on the cost of creating upland habitat in the local area • Reduction in heat-related fatalities, and associated value • Value of water quality and aquatic habitat improvements, based on household willingness to pay, acres of wetlands improved or created, and associated value of wetland services • Increased recreational user days, and associated values • Water conservation benefits from groundwater recharge, based on avoided imported water costs

The cost metrics listed in the exhibit represent engineering cost estimates, i.e., capital, O&M, life-cycle costs, as well as engineering estimates for specific performance measures used in cost-effectiveness analysis, e.g., pounds of total phosphorus removed or gallons of stormwater infiltrated. Many of the benefits listed in Exhibit 8 were quantified based on avoided costs associated with implementing LID/GI solutions such as a reduced need for traditional localized flood control infrastructure. Additional benefits were quantified based on willingness-to-pay values from the literature, market prices, and other economic modeling techniques.

5.3 Summary of Case Study Analyses

Exhibit 9 provides a summary of the economic analyses conducted by each case study entity, including the role and type of analysis, key metrics evaluated, and outcomes of the analysis. The case studies are presented in approximate order based on level of complexity of the economic analyses, from capital cost assessments to full BCA analyses that include social and environmental costs and benefits, as well as financial.

Exhibit 9. Summary of LID/GI case studies

Entity	LID/GI program description	Role of analysis	Type of analysis	Key metrics	Outcome of analysis
Lenexa Public Works Department, KS	Adoption of LID/GI-oriented development standards, BMPs, and systems development fees as part of the Rain to Recreation program.	• Evaluate impacts of development standards and fee • Gain support from developers prior to adoption	Capital cost assessment	Capital cost savings from implementation of BMPs compared to traditional development	Savings of tens to hundreds of thousands of dollars in site work and infrastructure costs with the application of LID/GI BMPs for different types of developments. In most cases, savings more than offset costs associated with the systems development fees. Analysis helped to gain developer support for standards and fee.
Charlotte-Mecklenburg Storm Water Services, NC	Restoration of streams damaged by runoff from development, and BMPs to reduce impacts of rapid development, were assessed to determine impacts on drinking water quality.	Project prioritization through evaluation of alternatives	Cost-effectiveness	Capital cost per pound of sediment prevented from entering stream and downstream drinking water reservoir	Analysis showed that stream restoration is the most cost-effective way to immediately control sediment in this area. Consequently, stream restoration is the focus of the county's program. Prioritization allows the county to implement need-based, rather than opportunity-based, projects.
Capitol Region Watershed District (CRWD), MN	Eighteen BMPs in a 298-acre watershed designed to reduce localized flooding and stormwater runoff, improve water quality, and enhance recreation in local park.	• Assess BMP effectiveness for pollutant removal and flood control • Guide future project development	• Capital cost assessment • Cost-effectiveness	• Capital cost savings • PV life-cycle costs • PV cost/pound removal of pollutants • PV cost/cubic foot stormwater reduction	Initial capital cost assessment found substantial cost savings with GI compared with grey infrastructure. This led to an analysis that helped CRWD validate an LID/GI-based watershed approach to water resource management and increased awareness of and support for GI.

Entity	LID/GI program description	Role of analysis	Type of analysis	Key metrics	Outcome of analysis
New York City Mayor's Office of Long-term Planning and Sustainability, NY	Distributed GI controls to reduce stormwater runoff and CSOs, improve water quality, and increase public access to tributaries, compared to conventional CSO controls such as tunnels and basin storage.	• Develop potential stormwater strategies • Prioritize pilot projects	Cost-effectiveness	• PV life-cycle costs • PV costs/gallon of runoff captured • Comparison of GI to grey infrastructure	Cost savings with GI compared to grey infrastructure. Analysis led the city to adopt 20 pilot projects, short-term strategies to supplement existing stormwater control efforts, medium-term strategies to develop cost-effective source controls, and long-term strategies to secure funding.
Seattle Public Utilities (SPU), WA	Natural drainage system (NDS) projects on residential streets; LID/GI-based stormwater regulations and Residential Rainwise Program to encourage customers to reduce the volume of stormwater sent to the public system.	• Identify economically feasible alternative for NDS street project • Integrate LID/GI into SPU's asset management program to enhance financial and public accountability	Cost-effectiveness	• PV capital and O&M costs • PV costs per greened acre • PV costs per kilogram TSS removed • PV cost per gallon of stormwater infiltrated	SPU identified most economically feasible options and proceeded with design phase. By integrating LID/GI into asset management process, SPU can minimize life-cycle costs to meet established levels of service and balance the risks to minimize life-cycle costs.
West Union, IA	Pilot community for Iowa Sustainable Green Streets Initiative to replace aging infrastructure and reduce localized flooding in downtown area.	• Gain support for project • Guide decision-making • Obtain funding	• Life-cycle cost analysis • Benefit valuation (avoided costs)	Cumulative life-cycle cost savings of permeable pavement compared to traditional	Lower maintenance and repair costs for deicing permeable pavement result in projected savings over the life-span of the pavement. Analysis helped West Union secure funding. Without it, grey infrastructure approach would have been implemented.
Kirkland Public Works Department, WA	Integration of LID/GI into conceptual design phase of all capital improvement projects within public rights-of-way.	Establish process for integrating LID/GI into CIP transportation projects	Quantitative ranking of costs and benefits	• Cost- effectiveness • LID/GI demonstration potential • Capital costs compared to grey infrastructure • O&M costs • Collaboration potential • Environmental and social benefits	Today nearly all CIP projects (including projects other than just transportation) contain LID/GI elements, including many of the projects evaluated in the feasibility study. LID/GI options for CIP projects are investigated as early in the planning phase as possible.

Entity	LID/GI program description	Role of analysis	Type of analysis	Key metrics	Outcome of analysis
Kane County, IL	Adoption of county stormwater ordinance and corresponding LID/GI-based BMPs, including development approaches that preserve natural areas and use naturalized drainage/retention/detention (i.e., conservation-based development).	Gain support from communities within Kane County for BMPs/conservation-based development	Fiscal impact analysis	County revenues and expenditures over time under conservation-based and conventional development alternatives	Study found that conservation development alternative incurs a lower public cost than the conventional alternative. Conservation-based BMPs were integrated into county stormwater ordinance/land development standards. In general, municipalities were supportive and responsive to the proposed land use changes.
Milwaukee Metropolitan Sewerage District (MMSD), WI	Integration of distributed LID/GI strategies into overall planning efforts including facilities plans and CSO control plan; projects on both public and private lands.	• Identify most cost-effective solution for integration of GI into pilot sewer shed management program • Demonstrate environmental and social benefits of GI	• Cost ef-fectiveness • Benefit valuation	• PV cost per stormwater volume reduction • Stormwater performance measures • Avoided grey infrastructure costs • Quantified (and some monetized) environmental and social benefits	Results will be used to help select which projects to implement in the future, and to show where the use of GI is a valid and effective approach. MMSD believes that the analysis will help MMSD employees, regulators, and the public understand the multiple benefits of GI and move it forward.
Alachua County Environmental Protection and Public Works Departments, FL	County acquires and preserves open-space lands through ACF program to reduce development impacts and improve water quality.	Demonstrate benefits of ACF to alleviate public concerns that the program reduces property tax revenue	Benefit-cost analysis (BCA)	• Increase in property values from increased open space • Lost tax revenue from acquiring private property for the ACF program	Proximity to open space adds to parcel value, for an increase in property tax revenue of several million dollars per year compared to not having the added open space parcels.

Entity	LID/GI program description	Role of analysis	Type of analysis	Key metrics	Outcome of analysis
Portland Bureau of Environmental Services (BES), OR	Ecoroof Program includes incentives for green roofs on privately owned buildings and green roof requirements for new city-owned buildings.	• Gain program support • Increase implementation of ecoroofs in the city	BCA analysis	1. PV life-cycle costs 2. Avoided costs 3. Environmental and social benefits 4. Net PV benefits	Ecoroofs generate significant public and environmental benefits, as well as benefits to developers and building owners (due to extended life of ecoroofs compared to traditional roofs). Documenting benefits has encouraged development of ecoroofs and justified the use of financial incentives to encourage private sector implementation.
Sun Valley Watershed, LACDPW, CA	Goal of watershed-based project was to alleviate localized flooding while providing multiple benefits. Fifteen project elements with LID/GI components.	Demonstrate higher benefit-cost ratio of GI compared with grey infrastructure (despite higher costs)	BCA analysis	• PV costs for capital, land, and O&M • Environmental and social benefits • Benefit-cost ratio	Demonstrated potential for multi-objective stormwater strategies to provide greater community value than a single-objective flood control strategy would provide. By quantifying benefits, LACDPW has engaged a wide range of agencies and stakeholders that might not otherwise have participated or provided funding for the program.
PWD, PA	Green City Clean Waters Program aims to reduce CSOs and improve water quality in part through distributed GI controls and comprehensive stream restoration program.	Demonstrate full range of societal benefits of GI to regulators and public	BCA analysis	• Net PV life-cycle costs and benefits of GI and grey approaches • Quantified and monetized social and environmental benefits	LID/GI-based approaches provide important environmental and social benefits that are generally not provided by grey infrastructure. Analysis helped PWD to determine that a GI-based approach, coupled with targeted grey infrastructure, is their preferred approach for city to follow.

6. Key Findings from the Case Study Economic Analyses

This section highlights the key findings from EPA's assessment of the economic analyses conducted by the case study entities.

6.1 Factors Influencing the Selection of Economic Analysis Methods

Utilities and other implementing agencies are using a variety of economic analysis techniques to evaluate stormwater management alternatives. As evidenced in the case studies, economic analyses can range in complexity from a simple assessment of the capital costs of various alternatives to a comprehensive evaluation of the non-market benefits and costs of LID/GI practices. The choice of a specific technique or type of analysis depends on a variety of factors, including the objective(s) of the economic analysis which may include gaining stakeholder support, alleviating public concerns, identification of economically feasible solutions, etc. Budgetary issues also may influence the analytic methods selected. A full BCA will provide decision makers the best information for use in policy development. However, budget, time, and availability of data can make a full BCA difficult to complete. In those situations a less rigorous analysis can be of use, such as qualitative ranking or cost-effectiveness.

Regardless of the type of analysis chosen, it is important to identify and qualitatively describe the benefits associated with different LID/GI approaches. (See Section 1.3, How to Use This Report, for additional ideas on how to select an appropriate analyses.)

6.2 Using Economic Analyses to Address Public Concerns and Gain Stakeholder Support

In the case studies that show that the adoption of LID/GI practices have a net positive value to society, this provides an important basis for addressing concerns expressed by the public and the development community and for gaining stakeholder support. Depending on the scope and application of the policies being considered, and the value assigned to benefits, not all analyses may show a net positive value. More specifically, economic analyses that found a net positive value from LID/GI were used to obtain:

- *Community and public support.* In response to public concern regarding the potential loss of property tax revenues associated with preservation of open-space lands, Alachua County, which includes Gainesville, Florida, conducted an economic analysis to quantify the change in property values that would result from the additional green space. The county analyzed real estate sales to show that the increase in land values for properties adjacent to open space more than offsets the property tax revenue loss associated with acquiring open

space for preservation. Kane County, IL conducted a fiscal impact study to gain support from the communities in the county for the integration of LID/GI-based BMPs into stormwater and land development standards. In partnership with the Conservation Foundation, Kane County presented its fiscal impact analysis to all 26 communities in Kane County. The analysis provided evidence that municipalities can save money by adopting conservation-based approaches for stormwater management. In general, municipalities supported the proposed land use changes. The Milwaukee Metropolitan Sewerage District (MMSD) also conducted a BCA analysis of the economic, environmental, and social benefits associated with one of its proposed LID/GI program options to garner public support for its GI approach. This analysis is an important component of MMSD's public education campaign.

- *Support and funding from a wide range of stakeholders.* By serving the interests of multiple stakeholders instead of a single-purpose flood control project, the Los Angeles County Department of Public Works (LACDPW) was able to gain the support of a wide range of agencies and stakeholders that might not otherwise have been interested in participating in or providing funding for its *Sun Valley Watershed Management Plan*. Supporting organizations included local, state, and federal agencies and nonprofit groups whose missions or activities are tied to the benefits achieved through the plan such as flood control, water quality protection and improvement, ground water recharge , ecosystem restoration, and recreation. LACDPW's BCA demonstrates the potential for multiple-objective stormwater strategies to provide greater value to the community than a single-objective flood control strategy.
- *Developer support.* Before adopting LID/GI-oriented development standards and a systems development fee for new development, the City of Lenexa (Kansas) analyzed potential impacts for different types of developments including residential, multi-family and commercial development. As noted above, the analysis showed substantial cost savings associated with implementing LID/GI-oriented BMPs compared to traditional development approaches. As a result of the analysis, the Lenexa City Council adopted the development standards and an accompanying BMP manual. In addition, the city gained developer support for adoption of the ordinance and the systems development fee. The Portland Bureau of Environmental Services (BES) conducted an economic analysis of the long-term costs and benefits of green roofs which convinced the Portland City Council to adopt a Green Building Policy that requires construction of an ecoroof for all new city-owned facilities and roof replacement projects if technically feasible. The policy includes an incentive that offers developers floor area bonuses, which allows additional building space to be constructed if the building is designed with green roofs. The main purpose of the Portland BES benefit-cost analysis of ecoroofs described in the case study was to provide further support for these programs and to encourage future construction of ecoroofs in the city. Alachua County used the results of its economic analysis of property values, described above, to alleviate potential concerns from the development community.
- *Cost-sharing support from Watershed Districts and other partners.* The Capitol Region Watershed District (CRWD) conducted cost-effectiveness evaluations to gain support from multiple jurisdictions for the implementation of an LID/GI approach to water resource management. The Los Angeles County Department of Public Works (LACDPW)

recognized the importance of involving the community to ensure success. By quantifying and monetizing the benefits associated with its proposed projects, the LACDPW was able to obtain support, including financial assistance, from a wide range of stakeholders and local agencies that might not otherwise have been interested in supporting the projects.

- *Local, state, and federal government policy and financial support.* West Union reports that the results of its economic analysis played an important role in gaining public and city council support for its Green Streets Pilot Project. The analysis also helped the city obtain financial support for the project because granting agencies were able to evaluate the positive economic aspects of the program as part of the grant application and review process. Results from the Philadelphia Water Department's (PWD) BCA (referred to by PWD as TBL analysis to emphasize the social, environmental, and financial aspects) were used not only to gain support from local stakeholders but also to encourage EPA to allow GI alternatives in combination with conventional CSO mitigation infrastructure.

6.3 Using Economic Studies to Optimize the Benefits of Infrastructure Investments

Utilities can use the results of economic analyses to prioritize and implement the most feasible or effective LID/GI approaches, and obtain a more clear understanding of the benefits of project or policy alternatives. For example:

- The Capitol Region Watershed District determined that LID/GI approaches could achieve stormwater runoff goals for its watershed managment project at a lower cost than the proposed construction of a 60-inch storm sewer pipe. CRWD then developed an approach for assessing the cost and effectiveness of LID/GI options. The findings were used to assess the relative costs and cost-effectiveness of the options in easily understood units such as dollars per pound of pollutant removed. This approach now serves as a water resource model for determining how to best achieve volume reduction and water quality in dense urban watersheds.

- Charlotte-Mecklenburg Storm Water Services initiated LID/GI approaches because model results indicated LID/GI was the only approach that could achieve sufficient pollutant removal and prevent further degradation of the county's waterways. The county's analysis showed that stream restoration was the most cost-effective way to immediately reduce sediment loadings through the stabilization of eroding streambeds damaged from excess urban runoff.

- New York City's Sustainable Stormwater Management Plan provides a comprehensive analysis of the feasibility and cost-effectiveness of stormwater management alternatives. The city found that its proposed LID/GI strategies—which include sidewalk standards, road reconstruction standards, green roadway infrastructure, and stormwater requirements and incentives for low- and medium-density residences and other existing buildings—present significant opportunities for cost-effectively controlling stormwater and reducing CSOs compared to the conventional pipe, tunnel and treatment alternatives for CSO control. Based on the analysis conducted as part of its *Sustainable Stormwater Management Plan*, the city developed and prioritized a series of promising stormwater

strategies and pilot projects. The pilot projects provide a framework for further testing, assessment, and implementation of decentralized source controls. Other analyses conducted by NYC point to some combination of significant cost savings, and higher net benefits compared to grey infrastructure approaches.

6.4 LID/GI Can Cost Less than Grey Infrastructure Alone

In addition to assessing the economic feasibility of LID/GI approaches, the case study entities used both simple and more complex economic analyses to compare LID/GI-based approaches with more traditional, solely grey infrastructure technologies. Many entities found cost savings associated with LID/GI-based alternatives. For example:

- The City of Lenexa, Kansas, found substantial cost savings associated with implementing LID/GI-oriented BMPs for multi-family, commercial, and warehouse developments in contrast to traditional stormwater management approaches using grey infrastructure.
- West Union, Iowa, compared the life-cycle costs (the total capital and O&M costs for the project) of a permeable paver system in the downtown area with those of traditional bituminous or Portland cement concrete pavement. Results showed that although permeable pavement will initially be more expensive, the lower maintenance and repair costs will result in cost savings in the long run. The city would begin to realize these cost savings by year 15 of the project. Estimated cumulative savings over a 57 year period were calculated to amount to about $2.5 million
- The Capitol Region Watershed District in Minnesota found significant capital cost savings for LID/GI approaches compared to grey infrastructure. A new storm sewer for conveying untreated, frequent floodwaters to Lake Como was estimated to cost $2.5 million compared to $2.0 million for implementing GI infiltration practices. In addition, the district found that LID/GI approaches would result in a significant benefit—by improving the quality of an economically important, nutrient-impaired recreational lake.
- In Portland, the Bureau of Environmental Services (BES) calculated the NPV of its ecoroof program to the public, i.e., the public stormwater system and the environment and to private property owners such as developers and building owners. BES concluded that ecoroof construction provides both an immediate and a long-term benefit to the public. The net present benefit is $101,660 at year 5 and $191,421 at year 40. For building owners, the benefits of ecoroofs do not exceed the costs until year 20, which is the point at which conventional roofs require replacement. In the long term for the 40-year life of an ecoroof, the net present benefit of ecoroofs to private stakeholders is more than $400,000.

6.5 LID/GI Approaches Result in Multiple Benefits

The multiple environmental, social, and financial benefits of LID/GI must be considered when determining the most appropriate approaches to implement. Almost all case study entities recognized the importance of the multiple benefits associated with LID/GI and developed both quantitative and qualitative ways to value these benefits when they made their stormwater management decisions.

In Milwaukee, Portland, Philadelphia, and the Sun Valley watershed of Los Angeles County, case study entities quantified and monetized benefits using non-market, or avoided cost, economic valuation techniques. Some entities identified the key benefits of LID/GI in their analysis but did not assign a value to those benefits. Several entities recognized the importance of the multiple benefits of LID/GI and indicated that they hope to be able to quantify the benefits in the future. Entities that incorporated these economic valuation techniques into their analyses include the following:

- The Portland Bureau of Environmental Services identified and/or quantified and monetized a wide range of benefits from ecoroof construction. Key benefits monetized in the city's benefit-cost analysis included (1) public benefits of reduced stormwater system management costs, habitat creation, improved air quality, and reduced carbon emissions and (2) private benefits to developers and building owners from stormwater volume reduction, reduced energy demand for heating and cooling, avoided stormwater facility costs, increased roof longevity, and reduced cost due to heating, ventilating, and air-conditioning equipment sizing. Portland found that, over time, the public and private benefits of ecoroofs exceed the costs.
- The Philadelphia Water Department performed a full BCA comparison of green versus grey infrastructure to evaluate the best approach for investing the city's funds to solve the CSO problem in a dense urban environment. The analysis demonstrated that for equal investment amounts and similar overflow volume reductions, the use of LID/GI would provide 20 times the benefits of traditional stormwater infrastructure such as large tunnels and pumping stations. The benefits quantified and monetized as part of this analysis included increased recreational opportunities, air quality improvements, water quality and ecosystem enhancement, creation of LID/GI-based jobs, increased property values, and reduced urban heat stress.
- The Los Angeles County Department of Public Works (LACDPW) monetized the multiple benefits associated with its proposed LID/GI-based alternatives, including benefits associated with water conservation, recreational opportunities, improved community aesthetics, increased wildlife habitat, and reduced stormwater pollution. By looking at the benefits per unit cost, rather than just lowest capital cost, LACDPW was able to provide a solution with more long-term value to the community and, also serve as a model for the region.
- The Capitol Region Watershed District (CRWD) and West Union did not quantify the non-market benefits associated with their LID/GI approaches but did recognize the important role such approaches played. CRWD recognized that the only benefit of the $2.5 million grey infrastructure alternative for stormwater management would have been to reduce localized flooding in Como Park. The $2.0 million LID/GI BMP option not only reduced flooding but also (1) reduced the volume of stormwater runoff which enhanced ground water supplies; (2) improved water quality in an impaired lake; and (3) enhanced the recreational amenities in Como Park. In West Union's life-cycle cost analysis of permeable versus traditional pavement systems, the city recognized, but did not quantify, the benefits of permeable pavement, such as improved water quality, increased stream health and appearance, reduced storm sewer infrastructure and maintenance, improved pavement surface temperatures, and improved street appearance.

6.6 LID/GI Approaches Can Be Successfully Integrated into Capital Improvement Programs

Economic analyses of LID/GI programs have been used to establish processes for capital improvement planning and other planning efforts. For example:

- The project evaluation matrix used in Kirkland's (WA State) feasibility study helped to provide the institutional framework needed to successfully incorporate LID/GI elements into the city's transportation CIP projects. Kirkland Public Works Department staff view the study as an important initial resource, and today most CIP projects (including non-transportation projects) contain LID/GI elements, including many of the projects evaluated in the feasibility study. Today, LID/GI options for CIP projects are investigated as early in the planning phase as possible.
- Subsequent to development of Fresh Coast Green Solutions, the Milwaukee Metropolitan Sewerage District (MMSD) initiated a more detailed analysis of the potential of GI strategies to help eliminate overflows and provide additional benefits. They produced a study called, *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee,* that is intended to be used to optimize the implementation of GI throughout MMSD's service area. As a result of these planning efforts, LID/GI has been integrated into MMSD's 2020 facilities planning effort, which is based on a watershed approach. Subsequent analyses and related reports will enhance integration of GI into the 2035 or 2040 facilities plans. (Planning will begin in 2013.) As part of its "adaptive management" approach to stormwater management, MMSD plans to continue evaluating the effectiveness and benefits of LID/GI practices as implementation becomes more widespread and more lessons are learned.
- A key outcome of Charlotte-Mecklenburg Storm Water Service's analysis is that Mecklenburg County (NC) has begun to shift from implementing opportunity-based projects to implementing need-based projects. This strategy includes the examination of a number of drivers that influence the selection and implementation of projects that will provide the largest benefits.
- The Los Angeles County Department of Public Works established the long-term benefits of LID/GI in the *Sun Valley Watershed Management Plan*. With the success of this approach, the Department now includes LID/GI analysis in future capital projects.

7. Lessons Learned

Case study entities used economic analysis to gain valuable insights, deal with unexpected challenges, and learn many valuable lessons. The challenge most frequently mentioned entailed difficulties in developing estimates of the costs and benefits of their LID/GI projects. A number of entities also noted lessons learned related to maintaining their LID/GI systems, as these are not familiar systems to most municipal stormwater maintenance crews. Many case study entities stressed the importance of stakeholder involvement throughout the development and implementation of LID/GI programs. In addition, many entities indicated they would like to improve or expand their analyses, perhaps by adding more program areas or monetizing more factors, but did not have the resources to do so.

As noted in the Introduction, the objectives of this document are to highlight different analysis methods that have been successfully applied and to demonstrate cases where LID/GI has been shown to be economically beneficial. The following sections highlight key lessons learned, as communicated by the case study participants.

7.1 Track and Analyze LID/GI Capital and O&M Costs to Plan and Budget Effective Programs

- *Track the costs of O&M activities over time.* Many case study entities indicated that they would like to obtain better estimates of the O&M costs associated with different types of LID/GI projects. The Seattle Public Utilities in Washington tracks information on the actual O&M costs of its NDS projects and uses this information to revise and improve estimates for new projects.
- *Review O&M and capital cost data from other entities, but be aware that these data might not apply to all situations.* For West Union, IA, for example, a key challenge in putting together its economic analysis was being able to compare up-front and long-term costs for LID/GI-based practices. The city found that urban-based estimates of costs and benefits did not transfer very well to its smaller, rural community. For example, West Union compared the capital and O&M costs of the permeable paver system with those associated with constructing and maintaining traditional types of pavement. Because West Union is a small community with limited resources, it lacks regular maintenance plans for its infrastructure. Thus, the city will not realize the same cost savings as larger cities that can better maintain their roads.
- *Develop accurate estimates of land acquisition costs.* Los Angles CDPW reports that costs associated with private land acquisition for LID/GI can be higher than originally anticipated. Given the county's financial situation, cost increases for some projects might affect the ability to implement future projects although LACDPW hopes to design future projects to capture more stormwater in order to reduce the need for projects in other locations.

7.2 Build LID/GI O&M Activities into the Program Framework

The use of LID/GI practices for stormwater management is a relatively new concept in many communities. When implementing these new technologies, many entities experienced unexpected maintenance concerns, as described below. Maintenance issues are expected to decrease as LID/GI implementation becomes more widespread.

- *Designate O&M responsibilities clearly.* Often, developers are not held responsible for O&M after they install recommended BMPs. In many instances the community is not able keep up with the maintenance, especially if it has no group or department to take charge. To deal with this problem, Kane County, IL initiated a special service area tax to fund the maintenance of stormwater management BMPs. When implementing a GI project on private lands, MMSD establishes a formal agreement with the property owner that lays out a cost-share and post-construction maintenance plan. MMSD has no liability for these projects. For CIP projects in residential areas, Kirkland, WA established partnerships with homeowners' associations to perform maintenance.
- *Expand staff skill set for different maintenance needs.* The skill set required for maintaining traditional CIP projects differs considerably from the skill set needed to maintain LID/GI components. As a result, maintenance staff might show some resistance, which has been a problem for some case study entities. The Kirkland Public Works Department sometimes obtains maintenance support from the Parks and Recreation Department. However, Kirkland considers supplemental training for CIP maintenance staff the long-term solution.
- *Educate public participants involved in LID/GI practices.* MMSD in Milwaukee, WI learned that in addition to requiring a formal agreement, projects on private lands are most successful when project owners understand and support GI and receive training on how to maintain the projects. It is also important to educate the public on how to keep conservation areas in their neighborhoods healthy by not mowing open-space areas intended to serve as prairie habitat and not tossing yard waste into wetland areas.
- *Seek associations and partnerships to reduce training costs.* Kirkland has supplemented its own training with training provided by a local nonprofit organization. It has also developed partnerships with homeowners' associations to maintain GI projects.

7.3 Encourage Stakeholder Involvement and Education

A key lesson learned by the case study entities is the importance of stakeholder involvement when developing and implementing LID/GI programs. Key stakeholders include decision makers, potential funders, partnering agencies, program staff, special interest groups, and the public. Examples of challenges and lessons learned related to stakeholder involvement are provided below.

- *Include stakeholders at all levels of decision making.* Lenexa's Rain to Recreation program is well supported by the city's residents and serves as a model for cities throughout the country. The city believes that this is largely because it has been open and transparent in developing its program and has included stakeholders throughout the process. For example, the city's BMP manual was developed through a cooperative effort led by the Kansas City

Metro Chapter of the American Public Works Association, in coordination with the Mid-American Regional Council and a host of municipalities in the Kansas City region. The city continues to work with development interests and hosted a BMP workshop for construction industry professionals. In addition, the system development fee adopted by the city council was the result of a multi-stakeholder process that included the Lenexa Economic Development Council and the Homebuilders Association.

LACDPW also stresses the importance of involving the community and other stakeholders at all levels of project design and implementation. LACDPW worked with an environmental nonprofit organization, TreePeople, to educate stakeholders at community events. The district also developed a project website that is actively used and frequently updated. Bringing stakeholders in early has been critical to LACDPW's success.

- *Gain support from agencies and staff involved in implementing LID/GI approaches.* New York City recognizes that a key challenge for its program will be to successfully coordinate the various agencies and stakeholders involved in implementing the stormwater management plan. Many agencies are supportive of LID/GI but are concerned about the operation and maintenance (O&M) costs associated with this type of infrastructure.

  When MMSD (Milwaukee, WI) began implementing GI in 2002, there was little support within the water and wastewater community or within the utility. In addition, although regulators such as EPA, the mayor, and the State of Wisconsin had been supportive, they were not fully on board with the GI approach. Gaining internal support was an initial critical concern. Support has increased over time because of successful demonstration projects, education, and the hiring of staff familiar with the GI approach. Overall, MMSD recognizes that although reducing overflows and improving water quality are its main concerns, TBL benefits are important.

- *Communicate the results of economic analyses.* Kane County, IL, believes that one reason its communities have been supportive of its watershed planning efforts is that the county's proposed programs and economic analysis were clearly communicated by a well-respected community member. The county also learned that it is necessary to clearly communicate with developers about new conservation requirements. Up-front communication encouraged developers to comply with these changes.

- *Use demonstration projects as a public education tool.* MMSD (Milwaukee, WI) achieved valuable public outreach benefits from its GI demonstration projects. For example, implementation of a rain garden demonstration project in a public building influenced local residents to install rain gardens in their own yards. Neighborhood associations and schools have also effectively brought ideas to the public.

- *Be open and transparent about assumptions.* The Philadelphia Water Department recognizes that analyses of social and environmental benefits invariably require the use of assumptions and approaches that interject uncertainty about the accuracy or comprehensiveness of the empirical results. Throughout its analysis, PWD was explicit and reasonable about its assumptions and approaches. For transparency purposes, the research team identified key omissions, biases, and uncertainties embedded in the analysis and described how the results of the analysis would likely have been affected, i.e., benefits would have increased, decreased, or changed in an uncertain direction if the omission or

data limitation had been avoidable. In conjunction with these issues, a series of sensitivity analyses were conducted to explore how changing some of the key assumptions would affect findings.

7.4 Plan and Budget Additional Analysis to Evaluate LID/GI Programs and Projects

Many case study entities indicated that they would like to conduct additional analysis, including quantifying or monetizing the benefits associated with their LID/GI projects and programs. In many cases, analysis has been limited by insufficient data or by a lack of available resources, expertise, or both. These needs for additional analysis are described below.

- *Identify ways to finance economic analyses.* Lack of available resources was cited as a primary reason for not conducting more in-depth analysis. For example, Kane County, IL considered conducting a fiscal impact analysis that would assess costs to developers, with the expectation that the costs associated with conservation-based systems would be lower than those associated with conventional systems and would also result in higher property values and higher profits. However, the county did not have sufficient resources to conduct such a study.
- *Investigate ways to quantify and/or monetize the benefits of LID/GI approaches.* Many case study entities indicated that they would like to be able to quantify and/or monetize the non-market or external benefits associated with LID/GI approaches but they lack the necessary expertise, data, or both to do so. For example, Portland BES quantified many of the benefits of ecoroofs and found that publicizing these benefits presents a convincing argument for the program. However, BES faced constraints in quantifying additional benefits, including difficulties in extrapolating findings from the literature to the City of Portland and monetizing benefits. Seattle Public Utilities conducts economic analysis of its proposed programs using cost-effectiveness analysis and some TBL components. However, the utility has not been able to quantify and/or monetize many of the environmental and social benefits of its projects because of a lack of available resources and expertise.

The case studies in this report provide a compelling case for the benefits of evaluating LID/GI, in combination with grey infrastructure, as an alternative to traditional grey-only stormwater infrastructure. As LID/GI practices become more established, it will become easier to identify, quantify, and monetize the benefits, and also to address the issues associated with O&M.

Appendix: LID/GI Case Studies

A.1 Sun Valley Watershed, California: Evaluating the Benefits of Using Green Infrastructure to Reduce Localized Flooding

Entity

Name: Los Angeles County Department of Public Works (LACDPW). The Sun Valley Watershed Management Project is directed by LACDPW. Members of the Sun Valley Watershed Stakeholders Group, other agencies, elected officials, civic groups, businesses, nonprofit organizations, and individuals are also involved in the decision-making process.

Population served: 80,000 residents within the watershed

Area: The Sun Valley watershed is in the San Fernando Valley, about 14 miles northwest of downtown Los Angeles. It encompasses the communities of Sun Valley and North Hollywood. The watershed is approximately 4.4 square miles and six miles in length from north to south.

Project highlights

By adopting a plan to alleviate local flooding problems while providing multiple benefits, including water conservation, recreational opportunities, improved community aesthetics, increased wildlife habitat, and reduced stormwater pollution, LACDPW has found:

- Although LID/GI-oriented solutions cost more than more traditional approaches in this setting, these solutions yield a much higher benefit-to-cost ratio.
- By looking at the benefits per unit cost, rather than just lowest capital cost, LACDPW was able to provide a solution with more long-term value to the community and, by leading by example, to the greater region at large.
- Public participation has been integral to the development and implementation of the watershed-based approach encompassed in the *Sun Valley Watershed Management Plan.*
- By quantifying and monetizing the benefits associated with proposed projects, LACDPW has been able to engage support, including financial assistance, from a wide range of agencies and stakeholders that might not otherwise have been interested in participating in the project or providing funding.
- In addition to the overall benefit-cost analysis undertaken as part of the plan, project-specific benefit-cost analyses will be necessary to further refine and, potentially, re-prioritize projects.

Background

For many years, the Sun Valley watershed has been faced with the need to solve its frequent flooding problems. This highly urbanized watershed is not served by a comprehensive underground storm drain system. During rainfall events, stormwater flows are conveyed along street surfaces, and water collects at several of the major intersections in the area. Even moderate

rainfall causes flooding on the order of two to three feet in depth, impeding pedestrian and vehicle traffic.

In addition to flooding problems, much of the runoff from the Sun Valley watershed is lost to the Los Angeles River as a result of the large amount of urbanization in the watershed. This has largely reduced infiltration and recharge, resulting in reduced availability of local groundwater supplies. In a region heavily dependent on imported water supply, the capture and reuse of runoff is an important benefit of Sun Valley's flood reduction program.

To alleviate the area's flooding problem, LACDPW initially proposed a storm drain project called Project 9250. The project involved constructing a system of storm drains throughout the watershed so that the majority of the stormwater flows would be conveyed below the streets. Project 9250 was last proposed in 1989, but it was never implemented, primarily because of a lack of funding and community support.

Although the storm drains would efficiently convey stormwater away from people and properties, this solution would not help to improve water quality in the Los Angeles River, which is listed as a 303(d) impaired water body largely because of urban runoff. The project would also not improve groundwater infiltration and recharge rates.

LACDPW, in coordination with a number of other agencies and stakeholder groups, has therefore proposed a series of LID/GI-oriented solutions as part of the *Sun Valley Watershed Management Plan*. The plan offers a multipurpose approach to stormwater management that is responsive to the need to integrate flood control, stormwater pollution reduction and water supply efforts. The plan also addresses additional community issues, such as the lack of recreational resources, wildlife habitat, and aesthetic amenities in the watershed.

Types of LID/GI solutions

The plan evaluates the feasibility of four stormwater management alternatives that consist of various combinations of specific LID/GI components focused on infiltration, water conservation, stormwater reuse, and subsurface conveyance systems and site specific BMPS such as mulching and tree planting. Example pilot project components include infiltration basins, e.g., Sun Valley Park Project, constructed wetlands, tree planting, development of parks and open space, and storm drains designed to convey stormwater to the project areas.

In addition, as part of the plan effort, Tree People, a nonprofit organization working in coordination with LACDPW, is working with Sun Valley residents to implement a green street project in the watershed. The project includes the construction of vegetated swales, structural elements to direct runoff from driveways into the swales, and cisterns.

Program description

Public participation has been integral to the development of the *Sun Valley Watershed Management Plan*. In 1998 LACDPW invited area residents, state and local agencies, local businesses, and environmental groups to form the Sun Valley Watershed Stakeholders Group. The purpose of this group is to develop a holistic solution to the area's flooding problem that

would be an alternative to traditional storm drains and would provide multiple benefits for the community. The mission of the group is:

> "*...to solve the local flooding problem while retaining all stormwater runoff from the watershed, increasing water conservation, recreational opportunities, and wildlife habitat, and reducing stormwater pollution.*"

LACDPW developed the objectives of the plan based on the mission statement of the group. Specific goals include:

- *Reduce local flooding*.
- *Increase water conservation.* The general goal for water conservation is to retain all stormwater runoff within the watershed for rainfall events up to the 50-year storm. Potential uses of captured stormwater include groundwater recharge to augment the local water supply and substitution for existing uses that do not require potable water, e.g., industrial washwaters or irrigation.
- *Increase recreational opportunities.* The plan contains a proposal for a series of flood control facilities designed to serve as parks, open space, or both. These areas will provide increased recreational opportunities for the residents of the Sun Valley watershed.
- *Increase wildlife habitat.* The plan incorporates flood control facilities designed to also serve as wildlife habitat areas. For this objective LACDPW follows the qualitative goals outlined in the *City of Los Angeles General Plan* (2001), which includes the following objective: "Protect and promote the restoration, to the greatest extent practical, of sensitive plant and animal species and their habitats." Examples of additional goals for habitat development include (1) increasing the number of species, (2) increasing the ratio of native to nonnative species, (3) increasing the diversity of native habitat types, and (4) connecting existing adjacent significant habitat areas.
- *Improve water quality.* Specific plan goals for improving water quality include reducing the pollutant load entering the Los Angeles River by retaining stormwater runoff within the watershed up to the 50-year frequency storm, improving the quality of urban runoff through use of stormwater quality BMPs, proactively enforcing regulations on illegal discharge, educating the public on responsible management practices, and maintaining or improving existing groundwater quality.
- *Provide additional environmental benefits.* The plan focuses on the development of strategies that will achieve multiple environmental benefits. For example, tree planting can help reduce urban runoff while providing shade for buildings, resulting in lower energy needs for air-conditioning. Project components incorporated into the plan aim to maximize these types of environmental benefits.
- *Increase multiple agency participation.* The plan aims to encourage a more involved government and community, attract multiple funding partners, work with local schools to provide aesthetic and other benefits for their campuses, and increase public awareness of watershed issues.

Using these goals and objectives, LACDPW developed a broad range of possible options. The range of possibilities was then narrowed down to four final alternatives, each of which was focused on a specific stormwater strategy: infiltration, water conservation, stormwater reuse, and urban storm protection that would be achieved (through the use of subsurface conveyance systems and regional BMPs). Each alternative is a collection of project components, and many of the components are used in more than one alternative. Examples of project components include infiltration basins, constructed wetlands, tree planting, street storage, parking lot infiltration, and tunnels or storm drains.

Exhibit A.1.1 provides a summary of the four sample alternatives.

Exhibit A.1.1. Final four sample alternatives of the Sun Valley Watershed Management Plan

	Alternative 1: Maximize infiltration	Alternative 2: Maximize water conservation	Alternative 3: Stormwater reuse	Alternative 4: Urban storm protection
Description	Widely distributed small projects	Maximizes wildlife habitat and water conservation	Maximizes stormwater reuse for industry	Maximizes subsurface conveyance and regional BMPs
Retention basin size	50 years	50 years in most watershed subareas	50 years	10 years
Net volume discharged to Los Angeles River in 50-year storm	21 acre-feet (AF)	0 AF	8 AF	598 AF

Alternative 2 had the highest benefit-to-cost ratio and has 15 proposed projects. Two of these projects have been completed—a groundwater recharge project at Sun Valley Park and an LID/GI-oriented flood reduction project aimed to alleviate flooding in a key intersection. The Sun Valley Park project uses GI to direct runoff into a treatment and infiltration system located underneath the park property. This project was used as a demonstration project to highlight partnerships between various agencies and organizations.

Currently, LACDPW is working on a third project called Strathern Pit. The project encompasses 46 acres and will direct water into a landfill for reclamation and a constructed wetland for treatment. The captured stormwater will then be pumped to Sun Valley Park for infiltration. The project will include the conversion of an active industrial area into a neighborhood park, and it will incorporate trails, recreational facilities, potentially include soccer fields and other park amenities. LACDPW plans to continue with the remaining 12 projects outlined in the watershed management plan.

In addition to the projects being implemented by LACDPW, the Los Angeles Department of Water and Power is taking the lead on implementing two projects. The projects include the implementation of treatment and infiltration BMPs on a 155-acre steam plant site and on a

smaller power line easement area. These two projects are not part of the Sun Valley Management Plan, but they stemmed from that effort.

Role of economic analysis

The objective of LACDPW's analysis was to evaluate the costs and benefits, including non-market benefits, e.g., air quality, water quality, of the four sample alternatives described above. This analysis allowed LACDPW and project partners to compare multi-objective solutions to the implementation of a more traditional approach to stormwater management, i.e., Project 9250.

The economic analysis was undertaken because the county and other stakeholders needed to show that although the costs of the LID/GI-oriented solutions would be much greater than the cost of traditional infrastructure, and they would yield significantly higher benefits. The results of the analysis were used to help to gain public support, bring in outside partners, and raise funds.

Economic analysis method and results

Method: Categories of benefits were developed based on project objectives and an understanding of future potential funding partners. Various methods were used to quantify these benefits, including using avoided costs, willingness to pay values from the literature, and valuation pricing, e.g., increases in property values. Project benefits and costs were evaluated over a 50-year time horizon, assuming a nominal discount rate of 4 percent. The benefits evaluated as part of LACDPW's analysis include:

- *Flood control*. Benefits include avoided cost of facilities needed to provide comparable local and downstream flood protection.
- *Water quality improvements*. Benefits include avoided costs associated with the removal of bacteria and other listed pollutants from waters that contribute to impairments of the Los Angeles River.
- *Water conservation*. Benefits include cost savings associated with the use of stormwater for ground water recharge and water supply augmentation compared to costs of purchasing imported water.
- *Energy*. Benefits include cost savings associated with reduced energy consumption due to the planting of shade trees and the decreased amount of energy used to pump imported water into the Los Angeles Basin due to alternative sources of water, i.e., harvested or infiltrated runoff.
- *Air quality improvements*. Benefits include absorption of pollutants by the tree canopy, pollution reduction achieved through reductions in vehicle emissions due to decreased greenwaste/yard trimming hauling, and reduced emissions from power plants from decreased energy consumption.
- *Greenwaste/yard trimming reduction*. The mulching component of the project would use all greenwaste that is generated at participating sites and thus reduce the waste stream to

landfills. Irrigation demand also would be reduced. Benefits include the avoided costs of hauling and tipping for landfill disposal of greenwaste.

- *Ecosystem restoration*. Benefits include increased habitat and open space.
- *Recreation*. Benefits include the value of increased parkland and recreation for the area.
- *Property values*. Benefits include increased property values due to proximity to the project site.

The costs of each alternative also were monetized. These costs included capital facilities costs, land acquisition costs, and expected O&M costs. Capital cost assumptions were developed based on costs obtained from industry manufacturers, contractor experience on similar planning projects, and data provided by LACDPW. Annual O&M costs were assumed to remain constant from year to year.

Results: The results of the benefit-cost analysis are summarized in Exhibit A.1.2, which shows the benefit-to-cost ratio for each alternative, including Project 9250. The ratios use the present value of total project costs and benefits over the 50-year evaluation period. A ratio greater than 1 indicates an alternative with benefits greater than cost; a ratio less than 1 indicates an alternative with costs greater than benefits.

Exhibit A.1.2. Benefit-to-cost ratio for each Sun Valley stormwater management alternative

Alternative	9250	Alternative 1: Infiltration	Alternative 2: Water conservation	Alternative 3: Stormwater reuse	Alternative 4: Urban storm protection
Present value (PV) of total benefits (millions 2002 USD)	$73.44	$270.47	$295.39	$274.93	$239.95
PV of total costs (millions 2002 USD)	$74.46	$230.40	$171.58	$297.90	$206.61
Benefit-to-cost ratio	0.99	1.17	1.72	0.92	1.16

As shown in Exhibit A.1.2, Alternative 2, water conservation, has the highest benefit-to-cost ratio at 1.72. This ratio is due to the combination of higher overall benefits and lower total project costs. The higher benefits are due primarily to the reduced costs associated with the Tujunga Wash to Sheldon Pit project. This alternative provides almost four times the groundwater recharge than that provided by any other alternative. This project involves the conveyance of water from an area highly prone to flooding (Tujunga Wash) to an exhausted gravel pit (Sheldon Pit) for infiltration and recharge.

The relatively low cost of the water conservation alternative results from a reduction in the number of retention projects to provide flood control for Sun Valley. This alternative also included fewer on-site BMPs and less street storage compared to the other alternatives.

Outcomes: The project has resulted in numerous positive outcomes. The benefit-cost analysis demonstrates the potential for multiple-objective stormwater strategies within the Sun Valley watershed to provide greater value to the community than a single-objective flood control strategy. By quantifying the large number of benefits associated with projects incorporated into the plan, LACDPW has been able to engage the support of a wide range of agencies and stakeholders that might not otherwise have been interested in participating in, or providing funding for, the plan. The agencies and stakeholders include local, state, and federal agencies and nonprofit groups whose missions or activities are tied to the benefit categories identified above, e.g., flood control, water quality improvements, ecosystem restoration, and recreation. A list of potential organization and agency partners is included in Section 5 of the plan (see http://www.sunvalleywatershed.org/ceqa_docs/plan.asp). To date, project partners that have provided financial assistance, services, or both include LACDPW, TreePeople, CALFED Bay Delta Program, California State Water Resources Control Board, City of Los Angeles Bureau of Sanitation, and City of Los Angeles Parks and Recreation.

As a result of this project's success, the county reorganized the LACDPW Flood Control Department which became the LACDPW Watershed Division. This change represents the shift toward a more holistic watershed approach.

The plan has helped LACDPW and other organizations, such as Tree People, to obtain funding for program activities. It is easier for these entities to obtain funding if they can point to the fact that they are undertaking proposed activities in coordination with a broad, adopted plan.

Residents also may benefit from implementation of the plan because increases in flooding insurance rates might be avoided. As background, there has been increased public awareness surrounding LACDPW's plan because Sun Valley residents may soon be subject to federal flood insurance requirements. If this area is determined to be in a National Flood Insurance Program flood zone, property values could be adversely affected, building restrictions could increase, and residents will have to pay for the required insurance if they hold a mortgage. Implementation of the plan might help alleviate this requirement.

The adoption of the plan also has increased public support. Residents of Sun Valley can see that progress is being made and that their concerns are being heard.

Lessons learned and next steps

In terms of the economic analysis, LACDPW will continue to conduct benefit-cost analyses on a project-by-project basis. The analysis presented in the plan was completed in 2004, and costs have since increased. More detailed analyses will be conducted for each planned project in order to evaluate implementation.

In addition, some projects, e.g., Strethern Pit will cost much more than originally anticipated, primarily because of unforeseen costs associated with private land acquisition. Given the county's current financial situation, cost increases for some projects might affect the ability to implement others. However, there may be opportunities to change the location and design of future projects to improve system function and perhaps reduce land acquisition costs.

Maintenance of the system has been an issue. Many of the projects implemented have high maintenance requirements, including maintenance associated with water quality monitoring, high-tech treatment systems, and the cleaning of underground treatment systems. For example, some projects require monthly calibration of monitoring probes, as well as removal of trash and cleaning after every storm. Maintenance needs are especially difficult for underground facilities; for example, air quality testing is required. LACDPW is considering design options to reduce maintenance needs. It should be noted that the plan does not take into account most of the maintenance costs associated with current projects and the city does not currently have a plan to evaluate these costs.

Although maintenance costs are more than those associated with surface controls such as LID/GI practices opportunities for the use of decentralized surficial source controls are limited in the Sun Valley watershed because of its highly urban nature and limited land availability. As a result, infiltration vaults and other regional projects will continue to be an important part of LACDPW's stormwater management program.

In addition to challenges associated with acquiring private lands for project implementation, LACDPW has had some difficulties working on public lands. For example, the county is working to implement a project at a local middle school, where flooding has been a large problem. LACDPW has proposed to put in a facility similar to the one constructed underneath Sun Valley Park. The school, however, is reluctant to let the county work on its property because it plans to expand in the future and is concerned that the project will limit its ability to place structures in certain areas. The two entities are working together to reach an agreement on project design.

Finally, LACDPW and the project stakeholders realize that to make the plan a reality, the community must be involved. Involvement is needed at many levels—for example, at the group level for making project design decisions and at the household and individual levels for tree planting, mulching, and using BMPs.

Progress is already well under way in educating and developing community interest and participation. TreePeople and LACDPW staff have made presentations at many community events. The project website is actively used and maintained. Monthly stakeholder meetings offer an opportunity for community members to provide ideas and feedback on project elements. Stakeholders who receive information at the meetings disseminate the information in the community.

Related links

Similar programs and analyses

Ventura, California's LID/GI-based program has many components similar to those included in Sun Valley's program. For more information, see http://www.surfrider.org/ventura/reports/Solving%20the%20Urban%20Runoff%20Problem%20-%20Ventura.pdf.

The City of Los Angeles has documented many of the benefits of GI implementation within the city. For more information, see the report *Green Infrastructure for Los Angeles: Addressing*

Urban Runoff and Water Supply through Low Impact Development. This report also contains a case study of Ventura's LID policies and programs. Available: http://www.waterboards.ca.gov/water_issues//programs/climate/docs/resources/la_green_infrastructure.pdf

Key sources

For more information on the Sun Valley Watershed Management Plan: www.sunvalleywatershed.org.

To view the City of Los Angeles General Plan (2001): http://cityplanning.lacity.org/.

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A.2 Alachua County, Florida: Preserving Suburban Lands to Improve Water Quality Provides a Good Return on Investment for the Community

Entity

Name: Alachua County, Environmental Protection Department (EPD) and Public Works Department (PWD)

Population served: 250,000 (includes Gainesville, Florida)

Area: 900 square miles

Project highlights

Alachua County acquires, protects, and manages environmentally significant lands in order to protect water resources, wildlife habitat, and natural areas suitable for resource-based recreation. Key findings and program successes include:

- The county's comprehensive program with open space set-aside requirements, incentives for low impact development (LID)/green infrastructure (GI), and intergovernmental collaboration provides an effective path to sustainable stormwater management.
- Regression analysis on real estate sales shows that the increase in land values for properties adjacent to open space more than offsets the property tax revenue loss associated with acquiring open space for preservation.
- The development of a ranking system for acquisitions, with water quality a priority, ensures that targeted goals are met.
- The program has won public support for land acquisition as evidenced by approval of bond referendums for the program.

Background

Like many counties in Florida, Alachua County has grappled with the negative impacts of suburbanization on natural systems, agriculture, and quality of life. In addition to the loss of forests, farms, and natural areas, past land development practices have been linked to water quality degradation throughout the county.

Since the mid-1990s, Alachua County also has experienced a sequence of extreme weather events, including historic floods, droughts, wildfires, and hurricanes. Predictions for Alachua County's climate change future suggest even greater extremes in weather conditions, temperatures, and water levels.

The impacts of development are a top priority for Alachua County residents. Water quality and other benefits associated with GI, e.g., recreation, ecosystem services, are seen as an important

component of the county's economy and quality of life. Citizens' concerns for these issues have driven the county's pursuit of GI programs.

To help mitigate the impacts of past land development, and to plan for expected growth and other impacts, the county has developed a comprehensive LID/GI program based on three different components: (1) LID/GI-based land development policies and regulations developed through the county's Comprehensive Plan; (2) Alachua County Forever (ACF), a conservation and land acquisition program; and (3) a unique governance structure designed to increase interdepartmental collaboration to promote the adoption of LID/GI program elements.

Types of LID/GI solutions

The county's program includes development standards that require and provide incentives for the use of GI on public and private lands, as well as preservation (through acquisition) of open space lands to improve water quality and provide other benefits. LID/GI practices encouraged under the development standards include enhanced stormwater pond designs, permeable pavement, vegetated swales and rain gardens, cisterns and rain barrels, underground tanks, parking islands and road medians with stormwater depressions and permeable parking areas.

The county has also implemented an educational program that includes advertising and the sale of rain barrels at large home improvement stores. To date, the county has held three rain barrel sale events that have had a high level of participation.

Program description

Alachua County's GI investment program relies on two major elements: the county's Comprehensive Plan (including development standards) and ACF. The county has also established a unique governance structure that emphasizes interdepartmental collaboration, systems thinking, performance management, and public involvement.

The first program component, Alachua County's updated Comprehensive Plan, went into effect in May, 2005. The plan is embedded with specific policies that require or provide incentives for the establishment of GI assets on public and private properties through updated land development regulations, e.g., a 20 percent open space set-aside common area requirement for most new developments, with additional protection required for specially designated areas such as wetlands, uplands, or special habitat areas. This program is administered through the County Department of Growth Management.

A challenge to implementing the new development standards has been developers' inability to obtain approval for GI approaches from state regional water management districts. In addition to obtaining local permits, developers also must obtain permits from their regional district. Some districts have not been approving the use of GI to meet stormwater management permit requirements. On the public works side, the public works department (PWD) is concerned about the maintenance needs associated with GI techniques.

The second component of the county's GI program is the ACF program, which is administered by EPD. Through ACF, the county acquires, protects, and manages environmentally significant

lands in order to protect water resources, wildlife habitat, and natural areas suitable for resource-based recreation. All property acquired under ACF must be nominated for purchase by a citizen of Alachua County. Since 2001, over 20,000 acres of lands valued highly for their environmental and ecosystem benefits have been preserved through ACF and its partners.

A key objective of ACF is to maximize the leverage of local investment through acquisition and management partnerships with municipalities, regional, state, and federal governments; nonprofits; and private entities. Since 2001, two-thirds of the $82 million investment for public acquisitions has been leveraged from outside sources. ACF has leveraged local funds by applying to state and federal granting programs, acquiring lands in partnership with regional water management districts, applying for transportation mitigation funds, working with nonprofit organizations to provide bridge loans and partnership funds, and facilitating donations of land and cash that meet both donors' charitable goals and ACF's conservation goals.

In deciding whether to purchase a particular parcel of land, county staff have developed a ranking system based on key attributes for potential properties. Improved water quality is the highest priority attribute. Public access, recreation, and habitat value are also key attributes used to influence the selection of properties for purchase. Although the benefits associated with these attributes are not monetized, they are ranked using an internal process developed by the department. This process is intended to take the politics out of choosing properties for purchase.

ACF has been relatively well received by county residents. In both 2000 and 2008, residents voted to raise taxes in order to help fund the program. Funding sources since then also have included grants, partnership contributions, and donations from various sources.

Role of economic analysis

The objective of the economic analysis was to demonstrate the benefits of the ACF program. The county evaluated how open-space lands affect surrounding home property values. The study was commissioned in response to citizen concerns regarding the perceived loss of property tax revenues due to county land acquisitions. The methods and results of this analysis are detailed in the county's report, *Open Space Proximity and Land Values.*

Economic analysis method and results

Method

To estimate the impact of open space on nearby home values, the county performed regression analysis on real estate sales based on data from the Alachua County Property Assessor. The Assessor's office maintains extensive data on all parcels in the county, including land use, buildings on the parcel, and sales information. The information for each parcel also includes the size and type of any buildings, the age of the buildings, heating and air-conditioning status, and the number of bedrooms and bathrooms. For each parcel, the county's consultant merged these data with the following:

- The parcel's census block location, that provides data about the population density and average income in the neighborhood in which the parcel is located.

- The parcel's distance from the central business district in downtown Gainesville.
- The parcel's proximity to water or open space, which is based on geographic information map layers for parks, open space, lakes, rivers, and creeks.

By combining these elements, the county was able to evaluate the effect on property sales prices in relationship to factors such as parcel size, building size, building age, distance from downtown, proximity to water, and proximity to open space.

Results: For most parcel types there is a strong correlation between parcel value and proximity to parks and open space. Other factors that affect parcel value include the type of parcel, e.g., single-family residential, vacant land, or condominiums, and location. For example, parcels in the densely settled parts of Gainesville had a lower correlated property value associated with proximity to open space than properties in less densely settled areas of the county.

Exhibit A.2.1 shows the results of the analysis (reported in 2004 U.S. dollars [2004 USD]). Proximity to open space adds about $8,000 to $10,000 to parcel value; for parcels in medium-density areas that touch open space and parcels of vacant land, the increase in value is as high as $25,000 per parcel.

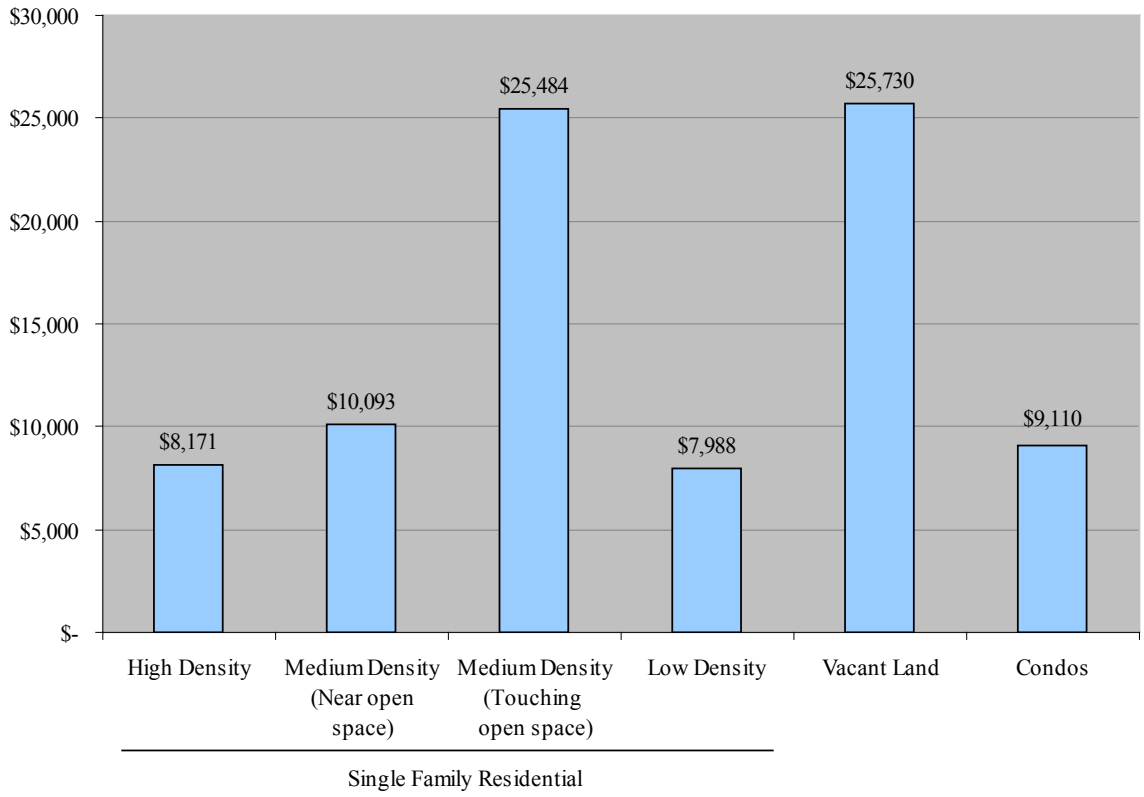

Exhibit A.2.1. Increase in property value due to open space proximity, by land use and population density of parcel neighborhood.

Source: Cape Ann Economics. 2004. Open Space Proximity and Land Values, Alachua County, FL.

The county's analysis also revealed that locations adjacent to water almost always had higher parcel values. As a result of this observation, proximity to water was treated as a separate factor which had more weight.

Twelve thousand seven hundred parcels in the county are close enough to open space to show an increase in value due to their proximity to water. The total impact on their value is just under $150 million, which would result in additional property tax revenues of approximately $3.5 million per year.

It is important to note that the results shown above reflect information for all open-space lands within the county rather than only those lands acquired under ACF. However, the county was able to demonstrate that less than $100,000 per year in tax revenues is taken out of the tax base each year because of the land acquisition program. This is because most of the land purchased is zoned for agricultural use. Agricultural land has a special, much lower tax rate compared to other property types.

Outcomes: As a result of this study, the county was able to gain further public support for the ACF program by demonstrating a feasible alternative to growth based approaches. The county believes that this analysis helped gain voter approval of the tax for the program in 2008.

Lessons learned and next steps

In hindsight, the county would have liked to focus its study on the effect of property values on the open-space lands it acquired under ACF, rather than on the values of all properties in close proximity to open-spaces in the county. The county has initiated a follow-up study to evaluate this effect.

The county anticipates introducing a bond program to fund certain aspects of the program. To garner support and promote a better understanding of GI, the county plans to provide information to the public that demonstrates that GI has a good return on investment and that the net benefits of GI are often higher than some traditional grey infrastructure practices. The county also would like to conduct analyses to educate the public about the suite of benefits GI practices provide such as carbon sequestration, improved quality of life, improved health, and enhanced water resource values.

Education is an important issue in terms of the overall program, particularly for acceptance of the LID/GI components of the development standards. The county believes it has a good program in place but feels that it lacks sufficient examples and data to prove that the program effectively reduces stormwater impacts and provides economic and social benefits. The county also noted that understanding what the public is willing to accept in terms of LID/GI is an important aspect of designing an effective program, given that location, cultural difference and housing density often affect public acceptance of what is acceptable or desirable in terms of development and growth.

Related links

Similar programs and analyses

In the Charles River watershed, located near Boston, Massachusetts, the Army Corps of Engineers has preserved wetlands and open spaces to store excess floodwaters and reduce damage on the upper and middle portions of the Charles River. Since 1977, the Army Corps of Engineers has been purchasing land and acquiring easements, prioritizing the parcels by location, storage capacity, and threat of development. For more information, see http://www.nae.usace.army.mil/Missions/CivilWorks/FloodRiskManagement/Massachusetts/CharlesRiverNVS.aspx.

As described in the Philadelphia case study, the Philadelphia Water Department also evaluated the potential impact of its proposed LID/GI program on surrounding property values.

Key sources

For more information on the development review standards, visit the Alachua County Environmental Protection Land Development Regulations page: http://www.alachuacounty.us/Depts/EPD/NaturalResources/Pages/LandDevelopmentRegulations.aspx

For more information on ACF, visit the Alachua County Environmental Protection Land Conservation page: http://www.alachuacounty.us/Depts/EPD/LandConservation/Pages/LandConservation.aspx.

To view the full property values report, *Open Space Proximity and Land Value*, visit http://www.alachuacounty.us/Depts/EPD/Documents/Land/Files/Alachua%20Write-up%20Jul%2004.pdf

To learn more about the ranking process for proposed land acquisitions, see the Alachua County Environmental Protection ACF Site Evaluation Scoring Matrix and criteria: http://www.alachuacounty.us/Depts/EPD/Documents/Land/site_scoring_criteria.pdf

The University of Florida Program for Resource Efficient Communities assisted Alachua County in promoting LID/GI and developing land development regulations and enhanced stormwater designs. For more information on this program, go to http://buildgreen.ufl.edu/.

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A.3 Kane County, Illinois, Blackberry Creek Watershed: Finding that Environmentally Sensitive Land Development Is Also Fiscally Responsible

Entity

Name: Kane County, Illinois

Population served: 511,892

Area: The Blackberry Creek watershed is in south central Kane County and north central Kendall County and is approximately 73 square miles in size. It includes portions of seven municipalities. The focus of this case study is on the 58 square mile area of Kane County portion of the watershed which is an outer-suburb of Chicago.

Project highlights

- Modeling performed by Kane County as part of the *Blackberry Creek Watershed Alternative Futures Analysis* was conducted to evaluate alternative land development scenarios. The results of the modeling indicated that with conventional development, the hydrologic, i.e., flooding, physical, i.e., streambank erosion, and biological, i.e., water quality and aquatic habitat conditions in the streams and wetlands of Blackberry Creek would likely degrade as the watershed continued to be urbanized. Conversely, these conditions would likely improve as conservation plans and practices are implemented.
- To further explore these findings, Kane County conducted a fiscal impact analysis to compare the effect of conventional versus conservation-based development on public costs and revenues, i.e., revenues and costs to the governmental units providing services to the development.
- The fiscal impact analysis found that between the two alternatives analyzed, conservation development imposes a lower net public cost based on analysis that examined population-based and land-based fiscal impacts.

Background

In July 1996, the Blackberry Creek watershed experienced significant flooding as a result of record rainfalls. This flooding prompted formation of the Blackberry Creek Watershed Resource Planning Committee and preparation of the *Blackberry Creek Watershed Management Plan*. After the plan was completed in 1999, it was adopted by Kane and Kendall counties and most of the municipalities within the Blackberry Creek watershed. A significant focus of the plan was the prevention of further flooding and degradation of stream and wetland resources due to future urbanization of the watershed. The plan addressed ways to resolve the flooding issues and other areas of concern such as water quality, biological integrity, and streambank erosion.

The existence of the comprehensive and environmentally focused *Blackberry Creek Watershed Management Plan*, the expected growth in central Kane County, and the region's flooding concerns was a positive factor influencing the decision by the U.S. Environmental Protection Agency (EPA) and the Illinois Department of Natural Resources to fund the study *Blackberry Creek Watershed Alternative Futures Analysis* The primary purpose of this analysis, completed in September 2003, was to evaluate the hydrological, physical, and biological impacts associated with potential "alternative futures" for land development in the Blackberry Creek watershed. The intent was to:

1. Investigate what would occur if current land use plans, development codes, and *conventional* development practices were followed.
2. Determine what might occur if *conservation*-based site design and ecologically sensitive land use planning were used.

Hydrological modeling was performed to assess biological health and aquatic habitat protection under each scenario, as well as impacts on flooding and streambank erosion. Kane County served as the lead agency for the analysis. The results of the Alternative Futures Analyses revealed that without the implementation of conservation-based development practices the watershed would continue to degrade.

To further explore these findings, Kane County (in partnership with EPA) initiated the *Blackberry Creek Watershed Alternative Futures Fiscal Impact Study*, which is the focus of this case study. The *Fiscal Impact Study* was conducted to explore the relationship between environmentally sensitive land development and fiscally responsible land development. The study analyzed the fiscal impacts of planned development within the Blackberry Creek watershed under the conventional and conservation-based development scenarios included in the *Alternatives Futures Analysis*. The purpose of a fiscal impact analysis is to estimate the impact of a development or a land use change on the costs and revenues of governmental units providing services to the development. The analysis is generally based on the fiscal characteristics of the community in terms of revenues, expenditures, and land values and the characteristics of the development or land use changes including the type of land uses and distance from central facilities. The analysis enables local governments to estimate the difference between the costs of providing services to a new development and the revenues—taxes and user fees, for example—that the development will generate.

LID/GI solutions

A variety of stormwater and landscaping BMPs were used in the design and development of the conservation-based development scenario included in the *Alternative Futures Analysis.* Many of these BMPs now have been incorporated into the County's Stormwater Management Ordinance. Also examined in the *Alternative Futures Analysis* were several planning/zoning BMPs that can be used to facilitate many of the stormwater BMPs.

Stormwater BMPs included in the conservation development scenario include bioswales, filter strips, green roofs, naturalized detention basins and drainageways, porous pavement, rain barrels/cisterns, rainwater gardens, vegetated swales, and native landscaping.

Planning and zoning BMPs included in the conservation development scenario include:

- *Conservation development practices.* These practices such as environmental site planning and design help preserve existing natural areas, enhance wildlife habitat, conserve energy, and improve transportation efficiency, largely through the use of natural drainage ways and onsite detention practices.
- *Impervious area reduction*. Impervious surfaces are reduced by narrowing streets, reducing street lengths in lower-density residential neighborhoods, the use of shared driveways and parking areas and the design of roads, walkways, and trails to minimize impervious surface area and provide multi-modal transportation routes.
- *Open space/natural greenways.* This practice is used to preserve and connect significant natural features for aesthetic, recreational, and/or alternative transportation uses.

Program description

Since the publication of the *Alternative Futures Analysis* and corresponding *Fiscal Impact Study*, Kane County has continued to take additional actions to reduce the negative impacts of stormwater and improve the quality of life in the Blackberry Creek watershed, e.g., the development of *a stormwater ordinance* and recommendations for watershed zoning code analysis and Ordinance Language.

The county's stormwater ordinance establishes a set of minimum standards for all new development within the county and associated municipal boundaries. Under the ordinance, ¾-inch rainfall or its equivalent must be retained or routed to extended detention facilities from the directly connected impervious surfaces created by the new development. All existing on-site wetlands must also be protected with buffers of varying length as determined by the quality and size of the wetlands. The ordinance also requires the establishment of special services areas (SSAs) for new developments for the purpose of funding the maintenance of stormwater management BMPs. The SSAs establish a tax that is paid by all residents in the development. This provides enough funds for the county to hire an outside contractor to maintain the BMPs.

In addition to the county-wide ordinance, Kane County also initiated an ordinance review to provide suggested ordinance revisions to each of the municipalities and counties within the watershed (see the *Blackberry Creek Zoning Code Analysis and Ordinance Language Recommendations*). Particular attention was paid to zoning and subdivision ordinances, and specifically those codes that pertain to the management of stormwater runoff. The ordinance review project resulted in the identification of potential changes to standards and codes for elements of development outside the typical realm and authority of the stormwater ordinance. For example, subdivision and zoning ordinances are used to control land use, whereas the stormwater ordinance does not address land use but rather how land is developed. One aspect of the ordinance review project was to develop language that communities could include in their subdivision and zoning ordinances to encourage land uses that will decrease runoff impacts.

Although the economic downturn has affected development in Kane County and the rate of LID/GI practice implementation, the county continues to plan for growth in an environmentally responsible manner. To date, the most common type of LID/GI practice that has been

implemented is naturalized detention basins—wetland systems with native vegetation and native vegetation on side slopes. The county also has successfully implemented several permeable pavement projects, narrow street designs, demonstration projects at the City of Aurora school, and a cluster development in Sugar Grove.

In addition to the *Blackberry Creek Watershed Management Plan*, which is being updated, the county is participating in the development and updating of watershed management plans for Ferson and Otter Creek, Sleepy and Jelkes Creek, and Tyler Creek. The county is using the *Alternative Futures Analysis* as a reference for these plans.

Role of economic analysis

The primary role of the *Fiscal Impact Study* was to gain support from the communities within Kane County for the BMPs included in the *Alternative Futures Analysis*. These BMPS were subsequently integrated into the county's stormwater ordinance/land development standards. The analysis also has served to provide input to the county's *2030 Land Resource Management Plan* and as a reference document/template for Kane County to be used to enhance coordination among municipalities and the development of integrated stormwater management strategies.

Economic analysis method and results

Method: In 2004 Kane County conducted the *Blackberry Creek Watershed Alternative Futures Fiscal Impact Study*, which compared the two development scenarios—conventional development and conservation development—described in the *Alternatives Futures Analysis.* Exhibit A.3.1 provides a summary of these scenarios. The basic hypothesis behind this study is that there is a neutral or positive relationship between environmentally sensitive land development and fiscally responsible land development.

Exhibit A.3.1. Alternative development scenarios used in alternative futures analysis

Conventional development alternative. This scenario was designed to examine the following land uses: Rural Estate Residential, Large-Lot Single-Family Residential, and Commercial. Average lot sizes for Rural Estate Residential and Large-Lot Residential are 58,200 and 12,500 square feet, respectively. For the Large-Lot Residential category, the development pattern includes conventional rights-of-way and stormwater controls, as well as infrastructure improvements such as public water supplies, sanitary sewers, storm sewers, sidewalks, and street and sidewalk designs.

Conservation development alternative. This scenario was used to examine Rural Residential, Moderate-Density Residential, and Commercial land uses. Average lot sizes for Rural Residential and Moderate-Density Residential are 21,385 and 7,685 square feet, respectively. The Conservation scenario represents a form of development in which the design is modified based on landscape topography and natural drainage patterns to utilize the natural infiltrative capacity of the landscape as much as possible. This design flexibility allows for a more concise development pattern or development footprint and leaves more land in open space because buildings are clustered. Using this approach also can reduce infrastructure such as pavement areas, curbs, gutters and other right-of-way impervious surfaces.

As a first step, Kane County used a land capacity model to evaluate the municipal infrastructure and services requirements associated with the conventional and conservation-based land development scenarios. This model was used to examine the impacts of local land development regulations and land use designations under each development scenario and convert these impacts into data that could be used to determine the fiscal impacts of land use decisions in the *Fiscal Impact Study*. For example, under a given development scenario, a community might require 10,000 square feet of lot area for a detached, single-family residence. However, the land area needed to support that residence includes additional land areas for streets, stormwater control, and other desired amenities.

The county used the outputs of the land capacity models, to run the Fiscal Impact Land Use Model (FILUM) (Dalstrom 2000) and analyze the overall relationship between county revenues and expenditures likely to occur over time under the two development alternatives. The analysis was applied to the entire unincorporated and undeveloped portion of the Blackberry Creek watershed located in the planning areas of the component communities; that area contains about 18,000 acres.

The analysis first examined revenues and costs as described below. These revenues and expenditures were then compared to evaluate the net public cost associated with the alternative development scenarios.

Revenues associated with development scenarios: The county used the FILUM model to estimate revenues associated with each development scenario, including:

- Real estate taxes.
- Sales tax distributions.
- Motor fuel tax rebates.
- State income tax rebates.
- Development impact fees.
- Building permit fees.

To estimate property tax revenues, the county first determined the fair market value (FMV) of future development based on a number of assumptions. The assessed value of a property was then determined based on the local assessment factor. The assessed value of a property is the basis upon which its tax liability is computed. In Kane County, developed residential, commercial, and industrial property is assessed at one-third of its FMV.

In Illinois, sales tax distributions are based on “point of sale.” Thus, projected sales tax receipts for Kane County are based on the sales potential associated with additional retail commercial space under the two development scenarios, and not on assumptions regarding the retail and service expenditures of new resident households. Further, the county applied a 20 percent “redistribution factor” that accounts for the overlap of new retail commercial operations with existing operations in the community.

Most other revenues were projected on the basis of population and dwelling units. For example, Illinois municipalities receive revenues from motor fuel tax and state income tax on a per capita

basis, whereas building permit fees and development impact fees are usually received on a per dwelling unit basis.

Expenditures associated with new development: To calculate expenditures (i.e., costs of providing services to the new development such as solid waste collection or street maintenance), the county used average cost methods to assign operational and capital costs to both development scenarios. Specifically, the county used a combination of costs per developed acre and costs per capita. This approach applies the ratio of developed land in the three principal private sector land use categories (residential, commercial, and industrial) to the budget to derive an assignment of municipal costs per developed acre. The resulting residential component of the budget is then divided by the population to derive a cost per capita.

Results: The study found that the conservation development alternative imposes a lower public cost than the conventional alternative. Exhibit A.3.2 provides a graphic comparison of the fiscal impacts of the conventional and conservation-based development scenarios. The vertical axis shows the net public cost, or the difference in expenditures and revenues under the two development scenarios.

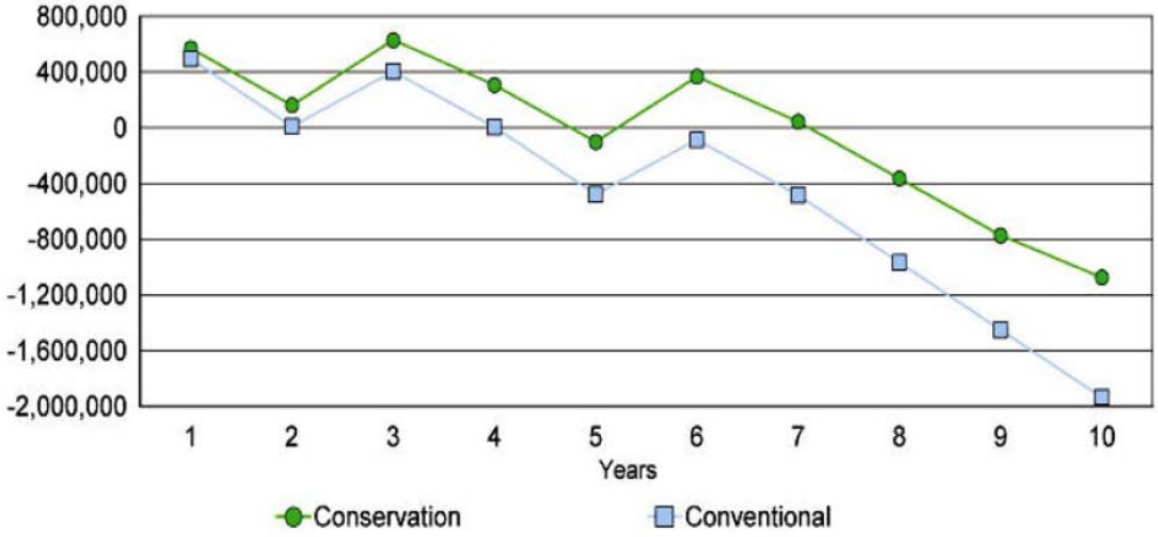

Exhibit A.3.2. Net public costs associated with conventional and conservation-based development scenarios.

As shown in Exhibit A.3.2, both the conventional and conservation-based scenarios result in a negative fiscal impact balance over the 10-year period. This result is not surprising given a development projection dominated by residential land uses (which are typically more expensive to maintain/provide services compared to commercial and industrial properties). However, the extent of the negative impact is reduced significantly under the conservation scenario. The downward trend of the projections results from the gradual reduction of revenue from one-time sources such as building permit fees and development impact fees combined with the cumulative nature of service costs.

The fiscal benefits of the conservation form of development result from the fact that reduced resources are required to support service delivery to, and infrastructure for, natural areas. In a given study area, it is likely that the extent of the benefit could vary considerably, whereas the existence of the benefit would remain constant. The county also found that to realize the potential public cost savings to the maximum extent, the clustering of development under the conservation scenario should be focused in a compact and contiguous form, locating development at the immediate periphery of the community wherever possible.

Outcomes: In partnership with the Conservation Foundation, Kane County presented the *Fiscal Impact Analysis* to all 26 communities within Kane County to gain support for conservation-based development and the stormwater ordinance. The fiscal impact analysis served as evidence that municipalities can save money by adopting many of the conservation-based approaches. In general, municipalities were supportive of and responsive to the proposed land use changes.

The county believes that since the *Alternative Futures Analysis* was published, there has been a real shift in support of conservation-based approaches. Communities and residents are beginning to understand how using these types of systems can improve water quality, reduce flooding, and help aquatics.

The *Blackberry Creek Alternative Futures Analysis* is still used and referred to by the county, and it will serve as an important input into the revised *Blackberry Creek Watershed Plan* (required by EPA for funding under section 319 of the Clean Water Act). Although the cost data used in the *Fiscal Impact Study* may have changed since the study was conducted, the overall results remain relatively unchanged. The studies have resulted in positive support for the stormwater ordinance.

Lessons learned and what's next

The County considered conducting a fiscal impact analysis that would assess costs to developers, with the expectation that the costs associated with conservation-based systems would be lower than those associated with conventional systems and would result in higher property values (meaning higher profits). However, the county did not have sufficient resources to conduct such a study.

Kane County believes that one reason its communities have been supportive is that the alternative futures analysis, stormwater ordinance, and fiscal impact analysis were clearly communicated by a well-respected community member.

The county has also learned that it is necessary to clearly communicate with developers about new conservation requirements. Up-front communication encourages developers to comply with these changes.

Maintenance of conservation-based techniques has been an issue for the county. Once the developers install the recommended BMPs, they do not believe they are responsible for maintenance, and in many cases the community is not able keep up with the maintenance (e.g., especially if it has no organized body to take charge). To deal with this problem, the county initiated the SSA tax (described above) to fund the maintenance of stormwater management BMPs. Another maintenance issue involves educating the public about how to help keep

conservation areas healthy (e.g., the public should not mow open-space areas intended to serve as prairie habitat or toss yard waste into wetland areas).

Related links

Kane County Stormwater Management. More information can be found at http://www.co.kane.il.us/kcstorm/.

Key sources

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A.4 West Union, Iowa: Long-Term Cost Savings Plus Environmental and Social Benefits Envisioned in Rural Green Streets Pilot Project

Entity

Name: City of West Union, Iowa, in partnership with the Iowa Department of Economic Development (IDED)

Population served: 2,500

Area: Project area includes the renovation of six downtown blocks

Project highlights

A main street "green street" is planned to revitalize a rural community's downtown features:

- Life-cycle cost analysis shows a cost savings associated with the use of a permeable pavement system when compared to the use of conventional asphalt. Payback begins at year 15.
- Other benefits include reduced flooding and water quality improvement from permeable pavements, biofiltration, and rain gardens.
- The results of economic analyses played an important role in gaining support and financing for the project.
- The green street project was part of a larger redevelopment plan for the downtown that, for example, included evaluation of a geothermal district heating system for buildings that could result in long-term savings.

Background

West Union, Iowa, has developed an integrated approach to community sustainability and livability through the Iowa Green Streets Pilot Project, which includes the complete renovation of six downtown blocks in West Union. The project will replace aging water, storm, and sanitary sewer infrastructure through the use of various LID/GI components. Primary objectives of the project include citizen safety, replacing aging infrastructure, improving water quality and habitat in a nearby trout stream, and reducing flooding in the downtown area. The project also is intended to serve as a catalyst for future investment in the historic downtown area.

Types of LID/GI solutions

The Green Streets Pilot Project involves a number of LID/GI techniques, including a permeable paver system for the roadway and sidewalks, rain gardens and biofiltration areas.

In addition to the LID/GI measures specifically related to stormwater management, the pilot project also includes a number of components intended to improve community livability and sustainability. These elements, which include the use of energy-efficient lighting, a district geothermal heating and cooling system, pedestrian-friendly crosswalks, and building energy performance improvements illustrate the need to take an integrated benefits approach to incorporation of innovative stormwater solutions into larger capital improvement projects.

Program description

In response to the need to replace aging infrastructure and reduce the risk of flooding in the downtown area, West Union had initially designed a very basic, traditional grey infrastructure stormwater project. At the same time, IDED's Downtown Resource Center (Main Street Iowa Program) had selected West Union as a model pilot community for demonstrating a holistic approach to implementing a sustainable green streets initiative. West Union was selected on the basis of a number of criteria, including its participation in the Main Street Iowa community, the existence of affordable housing projects in West Union, and its existing streetscape project plan that included the replacement of its aging water infrastructure. IDED provided technical assistance to help integrate these two projects.

This project began with a visioning workshop in October 2007, when IDED completed a technical assistance visit to advise West Union about the potential for multipurpose pedestrian-scale streetscape improvements. The result of the initial visioning and the subsequent conceptual and schematic planning was a streetscape master plan. The master plan includes many innovative, sustainable design strategies, such as permeable pavements, rain gardens, pedestrian crosswalk treatments, and energy-efficient lighting.

When completed, the project will be able to completely absorb runoff from a 10- to 20-year storm event. Additional project benefits include reduced flooding in the downtown area and improved recreation and ecosystem habitat.

It has been difficult for West Union, a very small town, to garner sufficient resources to complete the initial planning and design, including putting together a financing package, e.g., researching funding entities, submitting proposals, combining funding from several types of sources). To address these issues, IDED has provided assistance with up-front planning and has helped West Union to hire a grant application writer. The local Main Street organization, local businesses, and the city also have contributed to funding for the contacted grant writer.

The cost of the project has been a concern among members of the public and other stakeholders. The initial stormwater project the city had designed was estimated to cost between $3 million and $4 million. After the project was linked to downtown revitalization and focused more toward GI, the estimated cost increased to about $10.5 million, plus a $1 million contingency. Currently, about $8.5 million has been obtained through various sources, with the city paying approximately $3 million. Thus, the city is not paying any more than it would have for the original project.

Funding has been secured through the local and county governments, local organizations, IDED, the Iowa Department of Transportation, the Iowa Department of Cultural Affairs, the Iowa

Department of Natural Resources, the Iowa Department of Agriculture and Land Stewardship, and the U.S. Department of Agriculture (which provided funding for the district heating/cooling and ice melt feasibility study). The city is also investigating the use of tax-increment financing (TIF) to help fund the project. TIF is a financing method that uses future gains in taxes to finance current improvements (which theoretically will create the conditions for those future gains).

Role of economic analysis

The city has completed an economic analysis of the project to evaluate net benefits of the LID-based streetscape design compared to traditional infrastructure. Included in the analysis is a life-cycle analysis of permeable pavement costs versus traditional pavement costs, as well as an evaluation of savings associated with reduced road maintenance during snow or ice events, e.g., avoided costs as a result of reduced salting and plowing. Overall, these analyses were used to garner support for the project, guide decision-making, and obtain funding through various sources, e.g., federal agencies and grant programs.

Economic analysis method and results

Method. The city compared the life-cycle costs (including capital and O&M costs) associated with the use of a permeable paver system in the downtown area and those associated with using traditional bituminous or Portland cement concrete pavement. Cumulative costs were analyzed over a 57-year project period. As part of this analysis, the city recognized, but did not quantify, the benefits associated with porous pavement relative to traditional pavement, such as improved water quality, increased stream health and appearance, reduced storm sewer infrastructure and maintenance, improved pavement surface temperatures, i.e., retained heat, and improved street appearance. These benefits were not a driving force behind project implementation, but they helped to confirm the sustainability aspects of the project.

Project partners hope to document the benefits of the project on the trout stream that drains the downtown area. The Iowa Department of Natural Resources and Upper Iowa University have gathered pre-construction data on the stream in order to allow for a comparison to post-project conditions. The impacts and indicators measured include total pollutants, water temperature, and stormwater volume leaving the project area.

IDED and West Union would like to further research the impact of the permeable paver system on maintaining warmer temperatures on pavement surfaces in the winter, which could help to reduce the need for associated costs of snow plowing. These potential cost savings have not been evaluated, in part because the temperature effects are not yet fully understood.

Results: Results of the life-cycle analysis of different pavement types show that although the use of porous pavement will initially be more expensive, the lower maintenance and repair costs associated with cold weather and drainage will result in cost savings in the long run. The study indicates that the city would begin to realize these cost savings by year 15 of the project. Estimated cumulative savings over the 57-year analysis period amount to close to $2.5 million.

Outcomes: Based in part on the economic analysis of the project, IDED and West Union have been able to obtain support and secure additional funding for parts of the project from outside sources. Without this funding, the project most likely would have been implemented using the grey infrastructure approach that was originally planned.

Not all elements evaluated were selected. A geothermal street deicing system extending from the building geothermal system was evaluated, but ultimately not selected for implementation. An advantage of geothermal street deicing would have been a reduction in salts applied, reducing both costs and salt loading to nearby streams.

Lessons learned and next steps

A key challenge in putting together the economic analysis was being able to compare up-front costs and long-term costs for conventional practices with those for more sustainable practices. Urban-based analyses do not transfer very well to smaller, rural community situations. For example, for the economic analysis, the capital and O&M costs of the permeable paver system were compared to those associated with traditional types of pavement. In West Union, however, there is no regular maintenance plan for the infrastructure that is currently in place. Thus, the city will not realize cost savings if it is not maintaining the roads in the first place.

In addition, in terms of evaluating costs, there is a lack of existing data for newer innovative practices, and a number of assumptions must be made. West Union and IDED worked with the best information available, based on the local experience of the contracted engineering firm and the city's public works staff.

In terms of the overall project, one of the most significant barriers to implementation has been finding the time, expertise, and funding for planning and analysis. These resources are not often a priority or available in small communities. In addition, it is hard for small communities to find sufficient funding to cover capital costs. Even though communities might save in the long run by implementing LID/ GI measures, they also can be discouraged by the higher up-front capital costs associated with many LID/GI measures.

Finally, local support is crucial, but engaging the public can be difficult. It is important to work and communicate with the public early and often to prevent the spread of misinformation.

The next steps in implementing the project are to secure the remainder of the funding needed and to start construction of the geothermal component. The downtown street construction is nearly complete, and the district geothermal system component is scheduled to begin operation in 2013.

Related links

Similar programs and analyses

Both Seattle, Washington, and Ventura, California, have implemented comprehensive green street programs. For more information on Seattle's Green Streets program, see http://www.seattle.gov/util/MyServices/DrainageSewer/Projects/GreenStormwaterInfrastructure/CompletedGSIProjects/StreetEdgeAlternatives/index.htm.

For information on Ventura's LID and Green Streets programs, see http://www.venturariver.org/2008/07/ventura-adopts-green-streets-policy.html and http://www.surfrider.org/ventura/reports/Solving%20the%20Urban%20Runoff%20Problem%20-%20Ventura.pdf.

Key sources

For more information on the West Union Green Street Pilot Project, see "A Sustainable Vision for West Union: Integrated Green Infrastructure to Achieve a Renaissance of West Union's Downtown District and Neighborhoods" at http://www.westunion.com/uploads/PDF_File_67184288.pdf.

For more information on the West Union District Geothermal Project, see "West Union, Iowa: Small Town, Big Vision" at http://www.westunion.com/uploads/PDF_File_17418597.pdf.

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A.5 Lenexa, Kansas: Demonstrating Cost Savings Associated with New LID/GI Development Standards

Entity

Name: City of Lenexa Public Works Department, Watershed Division

Population served: 47,000

Area: 34 square miles

Project highlights

As part of its *Rain to Recreation* program, the City of Lenexa adopted LID/GI-oriented development standards and a systems development charge for new development:

- Prior to adoption of the standards and fee, the city analyzed potential impacts for different types of developments. The analysis showed substantial cost savings associated with the implementation of LID/GI-oriented BMPs compared to traditional development approaches.
- As a result of the analysis, the Lenexa City Council adopted the development standards and an accompanying BMP manual. In addition, the city gained developer support for the adoption of the ordinance and the systems development fee.

Background

The City of Lenexa encompasses a 34-square-mile area, approximately two-thirds of which is experiencing development pressure. The city is located just outside the metropolitan Kansas City area. In 2000, to accommodate rapid growth, the city developed a citizen-driven *Watershed Management Master Plan* that formed the basis of what is now the comprehensive GI-based stormwater management program, *Rain to Recreation*. The objectives of *Rain to Recreation* are to reduce flooding, improve water quality and habitat, and provide recreational opportunities.

Types of LID/GI solutions

The *Rain to Recreation* program consists of both regulatory and non-regulatory approaches to stormwater management. The program's non-regulatory measures include major capital projects, e.g., lakes that serve as regional retention facilities, land acquisition, and stream restoration projects, as well as LID/GI-based components such as green street improvements such as, bioretention cells and native vegetation plantings, rain gardens, and wetlands. The city also conducts outreach and education activities. Specific regulatory measures include protection of priority natural resource areas, a stream setback ordinance, and LID/GI standards/requirements for new development.

Program description

The *Watershed Management Master Plan* provided initial direction for the city's *Rain to Recreation* program in the form of policies, practices, and projects. The plan resulted in the construction of five regional retention facilities, lakes and numerous joint use detention facilities that provide passive recreational opportunities and, in some areas, serve as informal sports fields. Other elements of the plan include the creation of multipurpose regional stormwater facilities to provide flood protection and additional active and passive recreational opportunities.

Upon completion of the activities identified in the plan, the city continued to work toward sustainable stormwater management under Rain to Recreation. In March 2002 the city adopted a Stream Setback Ordinance. Today, LID/GI-based components of the program include stream restoration, e.g., streambank laybacks, native vegetation planting, urban stream restoration, green street improvements, rain gardens, bioretention areas, and wetlands.

In 2006 the city formed a "green crew" to implement stream restoration and GI projects in a more cost-effective way. As a result, the city has been able to complete a large majority of its stream restoration projects which ranged from $750,000 to several million dollars per project in-house.

In addition, in 2004 the City Council adopted new LID/GI development standards and an accompanying *Manual of Best Management Practices for Stormwater Quality* (BMP Manual). The development standards include decentralized LID/GI approaches such as native planting, bioswales, permeable pavement, bioretention cells, wet ponds, and open space. The BMP manual was developed through a cooperative effort led by the Kansas City Metro Chapter of the American Public Works Association (APWA), in coordination with the Mid-American Regional Council, and a host of municipalities within the Kansas City region. The city continues to work with the development interests and recently held a BMP workshop for construction industry professionals.

In conjunction with the new development standards, and as a result of a multi-stakeholder process that included the Lenexa Economic Development Council and the Homebuilders Association, the City Council also implemented a systems development charge. This is a one-time capital fee implemented to support the funding of programs necessary to manage runoff volumes associated with new development. The fee is based on impervious area and amounted to $956 per established equivalent dwelling unit (EDU) (2,750 square feet) in 2010; the fee is tied to the Consumer Price Index. Revenue from the fee has not been as large as expected because growth in the area has slowed.

In addition to the systems development fee, the city's program is funded through a variety of sources, including a temporary 1/8 of a cent sales tax that was approved by city residents in 1999 and 2004 by a 78 percent margin) and a stormwater utility fee for all residential and commercial parcels based on the amount of impervious surface. Continued grants from state and federal sources, such as the Clean Water Act Section 319 Nonpoint Source monies for park construction and Surface Transportation Project funding for roadway projects, have also helped to fund capital and demonstration projects. Monies appropriated through the American Reinvestment and Recovery Act and administered through the Clean Water State Revolving Fund was used to supplement a large stream restoration and revitalization project in the city center.

Role of economic analysis

To evaluate the impacts of the system development charge and the development standards prior to their adoption, the city analyzed the feasibility of BMP implementation for different types of developments. This analysis includes an evaluation of cost savings associated with implementation of the new LID-/GI-oriented BMPs compared to traditional development approaches. The results of this analysis were then compared to the total cost of the proposed systems development charge at each site. Results were used to justify adoption of the new standards and fee.

Economic analysis method and results

Method. The city analyzed the feasibility of implementing the BMPs described in the manual adopted as part of the development standards. The analysis used existing Lenexa site plans for proposed single-family residential, multi-family residential, commercial/retail, and warehouse/office developments.

BMPs that would meet specified water quality goals were selected for each development, e.g., LID/GI techniques such as native planting, permeable pavement, and bioswales. Next, the capital costs associated with BMP construction were estimated. Value engineering approaches were then applied to identify construction items that were originally considered that could be replaced or eliminated due to the inclusion of LID/GI BMPs. Resulting cost savings were determined, e.g., cost savings due to reduced earthwork and/or pavement needed because of the addition of LID/GI practices.

The benefits associated with the availability of additional developable land that was "recovered" by reducing stormwater detention facilities were also included in the calculations. For example, increased developable land allows commercial developers to build more retail space. For the commercial example, the benefit of this additional space was estimated to be $6 per square foot.

Finally, the systems development charge was calculated for each proposed development and the net savings, i.e., the difference between the anticipated cost reductions associated with BMP implementation and increase in costs due to the system development fee, were determined. This analysis shows how the implementation of BMPs can help to offset the proposed fee.

Results: Exhibit A.5.1 demonstrates the net savings associated with implementation of selected BMPs and application of the systems development charge to the existing development types.

Both the commercial/retail and warehouse/office examples demonstrated significant savings associated with the application of BMPs. The multi-family example demonstrated that LID/GI BMPs could be applied to multi-family developments. Single-family homeowners, in the example chosen for this analysis, would see an increase of $314 per home versus the full cost of the systems development charge ($956) if the developer applied stormwater quality LID/GI BMPs and reduced impervious surface in the residential development.

Exhibit A.5.1. Net impact of systems development fee and implementation of GI BMPs

Development type	EDUs	Increase in costs due to system development fee	Cost reductions associated with BMP implementation[a]	Net impact
Single family	221	$187,850	$118,420	-$69,430
Multi-family	100	$85,000	$89,043	$4,043
Commercial/retail	57	$48,450	$168,898	$120,448
Warehouse/office	356	$302,600	$317,483	$14,883

a. As noted above, BMP construction cost savings/benefits include cost savings associated with GI implementation compared to traditional infrastructure and the benefits associated with additional developable land.

In addition, Lenexa has found that stream setbacks and preservation through land acquisition have been the most cost-effective means of controlling stormwater through GI. Bioretention continues to be very expensive compared to rain gardens, and the city is leaning toward the implementation of more rain gardens.

Outcomes: The city was able to consistently demonstrate the savings of ranging from tens to hundreds of thousands of dollars in site work and infrastructure costs associated with the application of LID/GI and stormwater management BMPs. As a result, the Lenexa City Council adopted the new stormwater regulations and the APWA BMP manual on April 20, 2004, the first municipality in the Kansas City metropolitan area to do so. In addition, the city gained developer support for the adoption of the ordinance and a systems development fee, which was also adopted.

Lessons learned and next steps

Lenexa's Rain to Recreation program is highly supported by the city's residents and serves as a model for cities throughout the country. Recent (2009) polling data show citizen satisfaction with the Public Works Department-Stormwater Program at 84 percent. This satisfaction is largely due the fact that the city has been open and transparent and included stakeholders at all levels of decision-making.

As the program has progressed, compliance issues have driven expenditures and policy development. The City Council is now interested in the life-cycle costs associated with these efforts and would like more information on these costs in the future.

Financing the program may become more of a challenge for the city when the temporary sales taxes expire. Compounding matters, the city is responsible for maintaining and replacing more than 50 miles of corrugated metal pipe that is part of the city's stormwater management system. Paying for LID/GI and necessary grey infrastructure BMPs will require creative solutions to providing the necessary funding. It is envisioned that extensive use of LID/GI practices can reduce the financial burden of replacing and maintaining some of the grey infrastructure.

Related links

Examples of similar programs and analyses

The City of Overland Park has developed a multiple-objective sports complex based on Lenexa's model. More information on this project can be found at http://www.olssonassociates.com/our-projects/overland-park-soccer/index.html.

Key sources

For more information on Lenexa's Rain to Recreation program, see www.raintorecreation.org.

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A.6 Capitol Region Watershed District, Minnesota: Realizing Cost Savings and Environmental Benefits by Using Green Stormwater Infrastructure Retrofits

Entity

Name: Capitol Region Watershed District (CRWD)

CRWD is a special-purpose unit of government created to manage and protect the wetlands, creeks, and lakes in the watershed that eventually drain into the Mississippi River.

Population served: 245,000

Area: 41 square miles

Land use in the area is primarily residential, with tracts of commercial, industrial, and institutional uses dispersed throughout the watershed. The CRWD includes part of St. Paul, Minnesota, and the surrounding area (portions of five cities).

Project highlights

- *Capital cost savings compared to grey infrastructure.* A new storm sewer for conveying frequent floodwaters to Lake Como was estimated to cost $2.5 million compared to $2.0 million for implementing GI best management practices (BMPs).
- *Multiple benefits achieved.* The only benefit of the $2.5 million storm sewer pipe option would have been to reduce localized flooding in Como Park. The $2.0 million GI BMP option not only reduced flooding but also reduced the volume of stormwater runoff, increased groundwater supplies, improved water quality in an impaired recreational lake and enhanced the recreational amenities in Como Park.
- *High performance documented.* The GI BMPs provide high stormwater volume-reduction and pollutant-removal efficiencies.
- *Cost per pound of pollutant removed established.* The total annual cost for implementing the 18 stormwater GI BMPs was calculated to be $105,154. By pollutant, the annual costs per pound were $1,140/lb total phosphorus (TP), $0.32/lb total suspended solids (TSS); and $0.06/cubic foot stormwater volume reduction.
- *Multi-jurisdiction collaboration achieved.* CRWD brought together three cities and a county to deal cooperatively with drainage coming from their jurisdictions. Highlighting the benefits of the planned GI BMPs was key to achieving acceptance from all the stakeholders and developing successful partnerships.
- *Model approach adopted.* As a result of the project's success, the City of St. Paul now uses a similar design for under-the-street infiltration trenches for street reconstruction projects.

Background

Stormwater runoff is the most significant source of water pollution within CRWD. The area within CRWD is almost completely developed. Forty-two percent of the district is covered by impervious surfaces. Water quality is impaired and there is localized flooding. In addition, aging sewer infrastructure has caused drainage problems and sewer overflows. Both the Mississippi River and Como Lake are listed on the Minnesota Pollution Control Agency's 2008 list of impaired waters.

The highly developed nature of the district leaves little flexibility for stormwater management. When the CRWD evaluates BMPs, it is therefore primarily concerned with identifying areas to retrofit. Through its *Arlington Pascal Stormwater Improvement Project* (APSIP), CRWD has worked to reduce stormwater runoff volume and to improve water quality by reducing the amount of phosphorus, bacteria, mercury, nutrients, polychlorinated biphenyls, and turbidity discharged into Como Lake and the Mississippi River.

Types of LID/GI solutions

APSIP, substantially completed in 2007, consisted of 18 stormwater BMPs, including eight rain gardens to address volume control and water quality; eight underground (under-street) infiltration trenches to address stormwater rate and volume control; a large underground infiltration/storage facility to reduce flooding and improve water quality; and a regional stormwater pond, located on the Como Park Golf Course.

In addition to APSIP, CRWD has been involved in the implementation and construction of three green roof projects, two porous asphalt and concrete systems (parking lots), and numerous rain gardens within its service area.

Program description

A primary goal of CRWD's stormwater program is to protect, manage, and improve water resources through the implementation of BMPs that reduce stormwater runoff and remove pollutants. Monitoring the performance and cost-effectiveness of various BMPs in order to plan for future implementation is a key component of this goal.

Accordingly, CRWD has focused on implementation, monitoring, and assessment of BMPs as part of the APSIP. APSIP is a multi-jurisdictional, multi-partner project aimed at improving water quality in Como Lake. Specific goals of the project include:

- Reduce the frequency and duration of flooding.
- Address needed improvements in storm sewer pipes and roads.
- Reduce the TP and TSS loads to Como Lake.
- Determine an equitable distribution of costs among the jurisdictions.

Initially, the proposed solution to runoff problems in the Como Lake subwatershed included the construction of a second 60-inch storm sewer pipe that would convey untreated runoff to Como Lake at an estimated cost of $2.5 million (not including financing costs). This solution would reduce much of the localized flooding in Como Park but would not reduce stormwater runoff volume into Como Lake or improve water quality. The pipe would also result in severe disruption of the surrounding park area.

On the basis of a hydraulic evaluation conducted in 2003, CRWD and the project partners designed and constructed 18 stormwater BMPs that have achieved the project goals at a lower cost, approximately $2.0 million (not including financing costs). The APSIP BMPs include an underground stormwater storage and infiltration facility (Arlington-Hamline Underground Stormwater Facility/Arlington-Hamline Facility); a regional stormwater pond (Como Park Regional Pond); eight underground infiltration trenches; and eight rain gardens.

Construction of the BMPs began in 2005, and the last BMP constructed, the Como Park Regional Pond, became operational in late December 2007. CRWD monitors the performance of these BMPs and also conducts regular inspections and maintenance to ensure proper function.

For CRWD, the largest barrier to implementation has been access to land. CRWD does not own any land, and finding good locations for projects involves partnerships with public landowners which were mainly municipal governments. In the future, CRWD will look for more opportunities for partnerships with private landowners. CRWD recognizes that its water quality goals cannot be achieved without engaging all property owners in some way. The district is in the process of developing a 10-year management plan that will address this issue. It plans to focus first on commercial and industrial property owners with large areas of impervious surface.

As an important note, when CRWD began working on flooding and water quality problems in this subwatershed, there was not a focus on LID/GI solutions. In partnership with the municipalities within the district, GI BMPs were selected because they most efficiently and effectively accomplished the project goals. These solutions also provided multiple benefits, including improved water quality and reduced runoff volume discharged to Como Lake, amenity values associated with rain gardens and enhancements to the Como Lake Golf Course. These benefits were important in gaining neighborhood, city, and public acceptance.

APSIP was funded through CRWD's general fund levy, bonds, and partner contributions.

Role of economic analysis

APSIP provided CRWD with a good case study opportunity to evaluate the costs and cost-effectiveness of different types of BMPs. Upon implementation of the APSIP, CRWD initiated a comprehensive data collection and monitoring program to assess the effectiveness of the APSIP project components. The objectives of this program include:

- Determine the volume and pollutant load reductions and volume and pollutant removal efficiencies (performance) of the BMPs compared to modeled results.
- Determine the costs to construct, operate, and maintain the BMPs.
- Estimate the costs to remove pollutants (cost-effectiveness).

The resulting report, *Stormwater BMP Performance Assessment and Cost-Benefit Analysis* (completed in early 2010), is a comprehensive evaluation that presents actual and modeled performance results and maintenance data and analysis on select BMPs monitored or maintained by CRWD in 2007 and 2008. This analysis determined that the BMPs performed as well as, or better than, anticipated and it has helped guide future project development.

Economic analysis method and results

Method: CRWD's overall method involved calculating the costs and cost-effectiveness of each BMP. In 2007 and 2008, CRWD collected water quality and quantity data from the APSIP stormwater BMPs to determine their effectiveness in reducing stormwater runoff volume and pollutant loading. Total discharge volume, TP, and TSS loads were calculated for each storm event at every site using stage, flow, and water quality data. CRWD also assessed BMP conditions and conducted maintenance to ensure proper performance.

CRWD also estimated the annual costs associated with each of the BMPs, including amortized capital costs, operation and maintenance (O&M) costs, and periodic replacement. The cost-effectiveness, in terms of the cost per unit of stormwater volume reduction and pollutant removal, was then computed for each BMP (on an annual basis).

The annual cost of each BMP was calculated based on three steps. First, annual O&M costs were analyzed as part of the 2007/2008 monitoring effort. O&M costs were based on total cost of labor, equipment and materials, and contract services. To estimate these costs, CRWD used electronic field forms to record the BMP inspected or maintained, the inspection or maintenance activity occurring, time on and off site, and staff present on site. Projected annual O&M costs were also determined for each APSIP BMP based on expected labor, equipment and materials, and contract services costs of an average year using adjusted costs for future years.

Second, the total capital cost of each BMP was calculated by summing the costs of design, construction, and bond interest. Design and construction costs reflect the amount paid by CRWD and project partners. The bond interest cost reflects only the amount of the interest cost paid by CRWD; it does not include any interest paid by project partners. To determine annual capital costs, the capital costs for each BMP were amortized over the life expectancy of each BMP. A life expectancy of 35 years, which is an approximate average of individual BMP life expectancies, was assumed for each BMP.

Finally, CRWD determined total annual project costs by adding the annual capital cost of each BMP and the annual O&M costs for 2007, 2008, or the projected annual year. Irregular maintenance costs, such as dredging and bathymetric surveys, were also incorporated into the annual operating cost amount.

On the basis of this cost information, CRWD determined annual volume reduction and pollutant removal costs by dividing the total annual cost of each BMP for a given year by the total volume of runoff infiltrated or by the TP or TSS load removed in that same year, i.e., the cost of removing a pound of TP and a pound of TSS and the cost for reducing a cubic foot of stormwater volume. This approach allowed for a side-by-side comparison of BMP removal costs.

Results: CRWD found that properly designed, constructed, and maintained BMPs are exhibiting high-volume reduction and pollutant removal efficiencies. Importantly, CRWD found substantial cost savings associated with the implementation of the APSIP BMPs compared to the use of a more traditional 60-inch storm sewer pipe solution, i.e., a savings of approximately $0.5 million, excluding interest.

The APSIP has a total project capital cost of approximately $2.7 million, which includes the cost of design, construction, and financing costs over the 35-year project period. The project cost amounted to $2.0 million without financing costs, as reported above. The Como Park Regional Pond, which incorporates the largest drainage area and storage volume of the BMPs, has the highest capital cost. This project accounted for half of the total APSIP capital costs. The eight rain gardens have the lowest capital costs and the smallest drainage area and storage volume.

Exhibit A.6.1 shows the results of CRWD's analysis in terms of total annual project costs, i.e., amortized capital and O&M costs, and the cost per unit of pollutant removal and stormwater volume reduction.

Exhibit A.6.1. APSIP BMP annualized costs and cost-effectiveness

	Annualized costs (including annualized capital and O&M costs)	TP removal cost ($/lb)	TSS removal cost ($/lb)	Volume reduction cost ($/cf)
Arlington-Hamline facility	$27,473	$1,828	$0.54	$0.05
Como Park Regional Pond	$43,531	$714	$0.21	$0.00
Infiltration trenches	$23,769	$1,909	$0.60	$0.03
Rain gardens	$10,381	$2,791	$0.39	$0.04
Total APSIP costs	**$105,154**	**$1,140**	**$0.32**	**$0.06**[a]

a. The Como Park Regional Pond achieves no volume reduction. The project volume reduction cost is the total annual costs divided by the total annual volume reduction ($105k/1.7 million cf). This is why the volume reduction cost for the entire project is greater than that for any of the individual BMPs.

CRWD cautions that the costs reported in Exhibit A.6.1 must be evaluated on a project-by-project basis and are not directly comparable. For example, although the Como Park Regional Pond is more cost-effective for TP and TSS removal than some of the smaller, more decentralized BMPs, this type of solution is generally not feasible in a dense urban watershed. The pond also was relatively inexpensive because CRWD located the pond on land already in public ownership. CRWD noted that there are greater opportunities to use rain gardens and infiltration trenches because they can be integrated into redevelopment and street reconstruction projects in areas throughout the city while simultaneously providing improved aesthetic value. In addition, CRWD recognized the benefits of using retention based approaches to reduce streambank and bed erosion and reduce sediment discharges.

Outcomes: This analysis helped CRWD validate a watershed approach to water resource management. APSIP has served as a model for how to achieve volume reduction and water quality standards in dense urban watersheds. For example, the City of St. Paul now uses a similar

design for under-the-street infiltration trenches in order to comply with rules for street reconstruction projects.

This project enabled CRWD to bring together three cities and a county to cooperatively deal with drainage coming from their jurisdictions. The project has also increased awareness of and support for alternative approaches to stormwater management, from both the public and CRWD's member cities.

Lessons learned and next steps

CRWD developed the approach for the cost-effectiveness analysis without the benefit of having many examples to follow. The District looked at a few key questions that would help to move its program forward. These questions were: What are the costs?; Are these techniques effective?; and What is the balance between construction and O&M costs?. CRWD wanted to be able to prioritize projects based on these criteria. One difficulty the district encountered was being able to account for irregular maintenance costs. For example, Como Park Pond will need to be dredged and infiltration trenches will need to be cleaned out. However, it is difficult to determine how frequently these tasks will need to occur. To account for these costs, the District amortized on an annual basis the O&M costs over the project evaluation period (30 years) to determine an average O&M cost. In most years, CRWD will spend a lot less than the estimated average annual maintenance costs.

Although the analysis focuses primarily on BMP performance with regard to volume, TP and TSS reductions, CRWD sampled and analyzed other chemistry parameters. CRWD plans to further analyze water quality data collected to determine the effectiveness of the BMPs with respect to reduction of other pollutants such as metals and bacteria. CRWD is also interested in researching other entities that have come up with more effective approaches for documenting effectiveness and costs.

CRWD plans to continue to conduct similar types of analyses every two or three years. In subsequent studies, the district would like to quantify some of the secondary benefits of some of the BMPs to assess how they affect the communities' carbon footprint and mitigate urban heat island effects.

In terms of overall implementation, a key lesson learned is that patience, time, and money are keys to achieving acceptance from all the stakeholders. At the beginning of the project, there was significant reluctance, from both citizens and municipalities, to accept this new and different approach. To address citizen concerns, CRWD hosted public meetings and followed up with individuals. A significant amount of resources were directed toward gaining acceptance by the cities involved, agreeing upon an equitable funding allocation, and working with municipal engineers on effective project design.

The BMPs that have been implemented as part of APSIP have been constructed on public lands or within the public right-of-way often in in coordination with a major street reconstruction project. CRWD plans to continue to coordinate projects with redevelopment and street reconstruction projects. Since it is very expensive for CRWD to implement standalone projects, CRWD would like to get involved early in redevelopment projects so that stormwater features

can be integrated into the project at lower cost. CRWD is currently conducting several subwatershed analyses to identify BMP locations; this will give CRWD an opportunity to include the BMPs as part of redevelopment projects.

Related links

Examples of similar analyses and programs

Burnsville is another city in Minnesota using GI practices to improve lake water quality. Lacking space in the right-of-way to implement bioretention practices, Burnsville installed an experimental rain garden system to infiltrate street runoff. Rain gardens were installed on private property along streets, and they have reduced runoff by 90 percent. For more information, see http://www.ci.burnsville.mn.us/index.aspx?NID = 594.

Key sources

For more information on CRWD, see http://www.capitolregionwd.org/.

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A.7 New York City, New York: Bringing Together Agency Stakeholders to Assess the Cost-Effectiveness and Feasibility of Sustainable Stormwater Management in Combined Sewer Overflow Areas

Entity

Name: New York City (NYC) Mayor's Office of Long-Term Planning and Sustainability, *Sustainable Stormwater Management Plan*.

The plan was developed by an interagency task force as a key initiative under PlaNYC, the city's long-term plan for a greener, greater New York. The task force is composed of 14 city agencies responsible for infrastructure or development that have a direct impact on pollution in the city's waterways. Development and implementation of the plan are coordinated through the Mayor's Office of Long-term Planning and Sustainability.

Population served: 8.4 million

Area: 305 square miles, including all five boroughs

Project highlights

NYC's *Sustainable Stormwater Management Plan* is a comprehensive analysis of the feasibility and cost-effectiveness of various LID/GI and traditional grey infrastructure options to control stormwater runoff in the ultra-urban NYC setting. Highlights and key findings of the plan include:

- The implementation of LID/GI-oriented source control strategies is more cost-effective than the use of traditional grey infrastructure for NYC conditions.
- Based on the analysis conducted as part of the plan, the city has developed and prioritized a series of promising stormwater strategies and pilot projects. The pilot projects provide a framework for further testing, assessment, and implementation of decentralized source controls.
- The proposed strategies—which include sidewalk standards, road reconstruction standards, green roadway infrastructure, stormwater requirements and incentives for low- and medium-density residences and other existing buildings—present significant opportunities for controlling stormwater and reducing CSOs.
- The success of this plan will depend in part on the successful coordination of the many agencies and stakeholders involved.

Background

Stormwater runoff is one of the greatest water quality challenges in NYC. Inadequately managed runoff causes flooding in many areas and contributes to CSOs and other untreated discharges that

result in localized water quality problems. Stormwater runoff is a major reason that many of the tributaries in the city still do not meet standards for recreational use.

To address these issues, the city has developed a *Sustainable Stormwater Management Plan* as part of PlaNYC. PlaNYC's overall water quality goal is to improve public access and recreational use of the city's tributaries. The city has a goal to increase access from 48 percent today to 90 percent by 2030. Toward this end, the *Sustainable Stormwater Management Plan* evaluates the feasibility of various policies that when fully implemented will create a network of decentralized source controls to detain or capture over one billion additional gallons of stormwater annually. The plan creates a strategy for increasing the use of GI throughout the city for stormwater management purposes.

It is important to note that over the last 20 years, the city has drastically improved water quality in the New York harbor. Many areas meet water quality standards and are available for recreational use. As outlined in the plan, the city intends to continue these efforts through the implementation of GI primarily aimed at improving water quality in the tributaries.

Types of LID/GI solutions

The city's plan includes a variety of technological/structural and non-technological/nonstructural source control measures related to four specific program areas: the public right-of-way, city-owned property, open space, and private development. Technological source control measures include green roofs, blue roofs, rainwater harvesting, vegetated controls, tree planting, permeable pavements, and engineered/constructed wetlands. Non-technological measures include design guidelines, performance measures, zoning requirements, and economic incentives.

Program description

A key objective of the plan is to evaluate the technical and financial feasibility of source control strategies in order to plan for future implementation. Accordingly, the plan includes a preliminary analysis of a variety of GI measures. Based on this analysis, the plan identifies a number of promising source control strategies and policy initiatives that incorporate different combinations of these measures. These strategies have been developed at the planning level, and the details described below do not necessarily represent final implementation alternatives. Proposed strategies include:

- *Performance standards for new development.* Standards would require new development to detain a 10-year design storm with a gradual release rate through proven, cost-effective technologies such as rooftop detention practices such as blue roof and green roofs.
- *Performance standards for existing buildings.* Requirements for owners of existing buildings, with rooftops 10,000 square feet or greater, to meet a one-inch rooftop detention standard when replacing or making a major modification to the roof.
- *Low- and medium-density residential controls.* Retrofit of smaller existing buildings in low- and medium-density residential areas through public education efforts and economic incentives that encourage adoption of GI practices such as green roofs, cisterns, and rain

barrels. The city also is considering the adoption of performance standards for smaller buildings.

- *Road reconstruction design standards.* Installations of GI practices such as permeable pavement parking lanes and sidewalk biofiltration cells during scheduled road reconstruction projects.
- *Sidewalk design standards.* Installation of permeable pavement for sidewalks in the public right-of-way and sidewalks adjacent to private property in coordination with planned replacement schedules.
- *Expanding NYC's current Greenstreets program.* PlaNYC has already committed to implementing 80 new Greenstreets every year for the next decade. The plan evaluates the impacts of expanding this program, by either doubling the number of Greenstreets built every year or extending the commitment for an additional 12 years. The analyses revealed that in some watersheds, these additions could make significant contributions to runoff control, but the overall stormwater benefits would be small.
- *Right-of-way build-out.* One of the few remaining options is to expand beyond the portions of the roadway that will be reconstructed over the next 20 years. Any such retrofit program would be motivated by stormwater retention rather than roadway improvement.

Different types of GI measures included in these strategies will be tested through the implementation of 20 pilot projects, as identified in the plan. Construction of these projects began in early 2010. The practices constructed include vegetated swales, enhanced tree beds, permeable pavements, blue roofs and green roofs. The city intends to monitor the practices for several years.

In addition to the strategies identified above, the plan also builds upon a number of ongoing PlaNYC greening initiatives and other city efforts related to stormwater management. Examples include the planting of a million trees, reforesting 2,000 acres of parkland, zoning amendments requiring street trees and green parking lots, a green roof tax abatement program, public plazas in underutilized areas of the roadbed, additional engineered/constructed wetlands in the NYC Bluebelt system, and the conversion of asphalted areas and school playgrounds to turf and trees.

Following PlaNYC's framework of achieving multiple sustainability goals, the plan identifies opportunities to achieve complementary, non-stormwater benefits such as attractive tree-lined streets, public plazas, playgrounds, and other planted areas that are intended to transform the everyday life of city residents and reduce the urban heat island effects.

In terms of program funding, the city has budgeted millions of dollars toward stormwater management as a result of consent decree negotiations with the State of New York. NYC hopes to be able to allocate some of this money, which was originally slated for the implementation of traditional infrastructure, toward GI implementation. To reduce costs of the overall program, the city plans to implement GI in tandem with public works and other projects already planned for implementation such as parks, streets and public buildings. The city also is conducting a rate study to evaluate the benefits of implementing a stormwater fee based on impervious area in lieu of a flat fee.

Role of economic analysis

The plan is the city's first comprehensive analysis of the feasibility and cost-effectiveness of alternative methods for controlling stormwater. The proposed stormwater strategies and pilot projects were prioritized on the basis of this analysis. The pilot projects provide a framework for further testing, assessing, and implementing decentralized source controls.

Economic analysis method and results

Method: The plan provides a cost-effectiveness analysis that compares various LID/GI runoff control options to traditional grey infrastructure options. The city developed life-cycle cost estimates for a number of different measures, including the present value costs of installation, operation, and maintenance over the expected lifespan of the practices. The city analyzed both full and incremental costs. Full costs apply to measures implemented under an accelerated retrofit program that would install source controls on a schedule that is not coordinated with other construction. Incremental costs apply to source controls that are installed when roofs, sidewalks, and/or roads are already being replaced. For example if a roof is being replaced with the addition of a blue roof, the incremental cost would be the difference in cost between replacing the roof membrane and the addition of the blue roof elements.

The city was able to estimate total costs for various strategies and policy initiatives, and to prioritize strategies based on their analysis of the cost-effectiveness of the source control measures they evaluated. The city compared these costs to those associated with two planned grey infrastructure projects—the construction of proposed CSO storage tunnels for Newtown Creek and Flushing Bay.

Results: The city ranked the proposed strategies on the basis of two criteria—feasibility and cost. As shown in Exhibit A.7.1, these rankings reflect the fact that there is an upper limit to stormwater runoff reductions, and diminishing returns to cumulative investments in control options. For the most part, the costs shown below represent incremental costs (with the exception of some GI measures, such as rain barrels or cisterns that will be implemented independently of development/redevelopment, capital, or maintenance/replacement programs.

The city presented the costs above under the decision criterion that the most cost-effective strategies will be implemented first and that they will be fully implemented before additional options are implemented. The city, however, also recognizes that some of the appropriate practices can be implemented in parallel rather than sequentially. It also should be noted that the analysis was based only on stormwater benefits and not other ancillary benefits.

The city, however, recognizes the importance of non-stormwater benefits, including improved air quality, reduced energy demand, carbon sequestration, reduced greenhouse gas emissions, increased property values and aesthetics, habitat for birds and other wildlife, stream health and that the development of new local markets can stimulate job growth. At the time of this interview, the city had not yet been able to quantify or monetize these benefits, and these benefits have not been folded into the source control policy except as a deciding factor in the cases where stormwater costs are equal. Based on the results of planned pilot projects and future research, the city hopes to one day quantify these benefits in monetary terms.

Exhibit A.7.1. Cost comparison and prioritization of proposed control strategies

Source control strategy	Cumulative runoff capturea (million gallons)	Cumulative present value cost (2010–2030; millions)	Cumulative cost per gallon	Cost per gallon for individual source control
Performance standards for new development	1,174	$105	$0.09	$0.09
Performance standards for existing buildings (plus preceding strategy)	2,838	$416	$0.15	$0.19
Low- and medium-density residential controls (plus preceding strategies)	3,954	$625	$0.16	$0.19
Greenstreets (plus preceding strategies)	4,178	$676	$0.16	$0.23
Sidewalk standards (plus preceding strategies)	8,400	$1,704	$0.20	$0.24
Road reconstruction standards (plus preceding strategies)	9,868	$2,123	$0.22	$0.29
Right-of-way build-outs (plus preceding strategies)	24,092	$19,360	$0.80	$1.21
Grey infrastructure reference case	**Total CSO reduction**	**Total cost**		**Cost per gallon**
Potential future CSO detention facilities	2,266	$2,337		$1.03

a. Cumulative runoff capture for the source control scenarios refers to gallons of stormwater runoff that can be retained or detained in those source controls. The city has not yet established the exact relationship between these quantities and the corresponding reduction in CSOs.

Outcomes: The *Sustainable Stormwater Management Plan* can be characterized as a "plan to plan." The plan's analysis and other considerations led the city to adopt short-term strategies to supplement existing stormwater control efforts, medium-term strategies to develop innovative and cost-effective source controls, and long-term strategies to secure funding.

In the short term, the city recognizes significant opportunities, and few barriers, in adopting changes to local regulations to require stormwater performance standards in new developments.

For the medium term, the city identified several source control strategies for implementation. These strategies—sidewalk standards, road reconstruction standards, green roadway infrastructure, and stormwater requirements and incentives for low- and medium-density residences and other existing buildings—present significant opportunities. The city, however, plans to further vet each of the strategies, based on pilot project results, studies of economic incentives, resolution of funding and maintenance issues, and settlement on consensus designs.

In the long term, the city will continue to assess stormwater controls at regular intervals to determine the need for additional measures. Future performance assessments of the effectiveness and implementation of source controls could affect decisions regarding the construction of projects slated for implementation. For example, based on such an evaluation, the plans to build

expensive grey infrastructure such as deep storage tunnels for stormwater in Newtown Creek and Flushing Bay could result in the downsizing or elimination of such projects.

The city also will continue to evaluate long-term funding strategies. There are at least five potential types of sources for funding stormwater initiatives: (1) rate increases, designated stormwater rates, or a combination of these fees approved by the independent Water Board; (2) the general municipal fund; (3) outside funding from other funders including the New York State Department of State, New York State Environmental Protection Fund, private foundations and natural resource damage assessment settlements; (4) increased federal funds for infrastructure improvements; and, (5) funds redirected from conventional infrastructure towards more cost-effective solutions.

Lessons learned and next steps

The city is pleased with the outcome of the plan in terms of the economic data it provided. Although the plan indicates that there is tremendous potential for GI in NYC, further testing is needed. In the future the city would like to examine the costs and benefits of GI at the watershed level rather than from a city-wide perspective.

A key challenge of the program will be the successful coordination of the various agencies and stakeholders involved in the plan. For example, a project in the public right-of-way must be coordinated across several different agencies, including the Department of Transportation, the Parks Department, the City's Water and Sewer departments, and the Department of Sanitation (and possibly more). The Mayor's Office is tasked with trying to coordinate communication and cooperation across agencies from the outset of each project. This level of coordination requires new relationships and the involvement of agencies whose core mission has not traditionally been water quality improvement.

In addition, many of the agencies that will be involved in the implementation of GI are supportive but have concerns related to the O&M costs associated with this type of infrastructure. Some GI projects do require more maintenance than traditional infrastructure. Additional staff training or equipment such as vacuum sweepers for porous pavement will be required. Consequently, agencies will need to secure additional funding to be able to adequately maintain and operate GI projects.

Related links

Similar programs and analyses

NYC has used LID/GI approaches to address sewer overflow problems on Staten Island since 1991. The Staten Island Bluebelt facilities include constructed wetlands, basins, and filters designed to slow runoff, remove contaminants, minimize erosion and flooding, and promote groundwater infiltration. For more information on this program, see http://www.nyc.gov/html/dep/html/dep_projects/bluebelt.shtml.

Indianapolis' planned LID/GI program is focused on encouraging the use of GI in the private sector and implementing projects on city operations. The city has developed a GI master plan to help guide implementation of future GI projects. CSO control is the main driver of the program.

For more information, see
http://www.indygov.org/eGov/City/DPW/SustainIndy/Pages/home.aspx.

Key sources

To download a copy of PlaNYC's *Sustainable Stormwater Management Plan*:
http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/nyc_sustainable_stormwater_management_plan_final.pdf

The 2012 update of the *Sustainable Stormwater Management Plan* can be found at:
http://nytelecom.vo.llnwd.net/o15/agencies/planyc2030/pdf/sustainable_stormwater_mgmt_plan_progress_report_october_2012.pdf

To view the overall PlaNYC: http://www.nyc.gov/html/planyc2030/html/home/home.shtml.

To access the Department of Environmental Protection (key agency in the development and implementation of the plan):
http://www.nyc.gov/html/dep/html/home/home.shtml.

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A.8 Charlotte-Mecklenburg Storm Water Services, North Carolina: Using Cost-Effectiveness Analyses to Prioritize Projects that Reduce the Impacts of Rapid Development

Entity

Name: Charlotte-Mecklenburg Storm Water Services (CMSWS)

Charlotte-Mecklenburg Storm Water Services is a stormwater utility that is staffed by both city and county personnel. About 60 percent of the staff of CMSWS work for the City of Charlotte, while the other 40 percent work for Mecklenburg County Land Use and Environmental Services Agency.

Population served: 890,000

Area: 526 square miles

Project highlights

Mecklenburg County has used LID/GI approaches to reduce the impacts of rapid development on water quality for several years:

- LID/GI approaches were initiated because model results indicated LID/GI was the only approach that would achieve sufficient pollutant removal and prevent further degradation of the county's waterways given that traditional stormwater management practices had failed to prevent sediment buildup in the drinking water reservoir resulting from runoff and stream erosion.
- The county conducted a cost-effectiveness analysis in a key watershed to determine cost per pound of sediment saved for various LID/GI program components. Results show that for this area, stream restoration is the most cost-effective means of controlling sediment. Stream restoration techniques cost on average between $0.60 to $1.00 per pound of sediment managed compared to the sediment removal costs that wet ponds and extended detention wet ponds provided ($35 and $69 per pond removed respectively excluding land costs).
- Implementation of an LID/GI-based post-construction ordinance in Huntersville (which is a municipality in the county) to mitigate water quality degradation from future development.
- The county recognizes the importance of using wetlands, vegetated swales and other GI practices to improve water quality in developed areas.

Background

The primary objective of Mecklenburg County's stormwater program is to protect drinking water quality and water quality in general. Enhancement of recreational amenities, wildlife habitat and the protection of endangered species also are goals of the county. Increases in volumes of

stormwater runoff and associated pollutants due to rapid development have been identified as the biggest threat to water quality in this region.

There are three priority watersheds in the county: McDowell Creek, Goose Creek, and Gar Creek. Most of the major creeks in this region are listed as being water quality impaired, due to sediment, under section 303(d) of the Clean Water Act. Several drivers influence the program priorities. McDowell Creek empties directly into the Catawba River which is the primary source of drinking water supply for the area. For this reason, the McDowell Creek watershed is the primary focus of activity for the county's LID/GI program. The Carolina heel splitter, an endangered freshwater mussel species, is found in Goose Creek, and there is a total maximum daily load calculated for Goose Creek.

Types of LID/GI solutions

The county's capital improvement project (CIP) program has three primary LID/GI-based focus areas: in-stream restoration, upland BMP retrofits, e.g., rain gardens, bioswales, and reforestation. In addition, the Town of Huntersville has implemented a post-construction LID-based ordinance intended to mitigate water quality degradation from future development.

Program description

Mecklenburg County's stormwater program is implemented through Charlotte-Mecklenburg Storm Water Services, a single stormwater utility that serves the City of Charlotte, Mecklenburg County, and six incorporated towns.

The City of Charlotte and Mecklenburg County have divided stormwater responsibilities between themselves based on their "major" and "minor" stormwater systems. The county is responsible for the major system, which includes streams that have watersheds greater than one square mile in size. The City of Charlotte and the six surrounding towns are responsible for the minor systems within each jurisdiction. Minor systems are defined as tributaries, channels, pipes, catch basins, and culverts located on private property or in the street right-of-way and draining less than one square mile of land.

The county has been implementing LID/GI-based approaches for more than 10 years. The LID/GI components of the county's stormwater program were initiated based on a watershed modeling exercise developed for McDowell Creek. The model was used to compare the effectiveness of alternative stormwater management approaches to that of existing practices at build-out/full development conditions. This is a practice known as future conditions modeling, which has helped communities make more sustainable long-term planning decisions. During the development of the post-construction ordinance, this type of modeling was also used to evaluate the effectiveness of LID/GI-based BMPs in preventing flooding.

The modeling effort was undertaken because the county recognized that its current approach to stormwater management, which included traditional stormwater infrastructure, was not working. McDowell Creek was listed as a 303(d) impaired water body for benthic impairment and the county's downstream drinking water supply reservoir had elevated levels of nutrients. The county understood that future development would only intensify these problems. Model results

indicated LID/GI was the only approach that would achieve sufficient pollutant removal and prevent further degradation of the county's waterways. Today, LID/GI is implemented in combination with conventional approaches designed to manage larger storms.

The majority of the county's resources are used to implement stream restoration projects, which typically involve modification of the stream profile and structure, i.e., a complete reengineering of the channel to accommodate increases in stormwater from development and prevent habitat degradation. These types of projects provide the county with the "biggest bang for its buck" in terms of stormwater benefits.

Upland BMP retrofit projects used by CMSWS include rain gardens and vegetated swales. Wet pond retrofit are also included in the set of practices employed to increase the effectiveness of the pond in terms of pollutant removal. These projects have been implemented in addition to the county's Phase 1 and 2 permit requirements.

In the McDowell Creek watershed, two LID/GI projects are under construction, two LID/GI projects are in the planning phase, and two additional projects are in the very early stages of evaluation. The projects under construction include a 3 million dollar 3 mile long stream restoration project and a small-scale BMP retrofit project.

The county prioritizes projects based on the following:

- Cost-effectiveness and feasibility, which includes the landowner acceptance and ability to obtain an easement.
- Flood reduction benefits.
- Improvements to drinking water quality.
- Improvements to water quality in listed streams.
- Improvements to habitat and endangered/listed species.

Using this prioritization scheme, the county strives to implement need-based projects rather than opportunity-based projects, i.e., projects where land is available but less cost effective overall.

Obtaining easements from landowners in high-priority project areas has been the most significant stumbling block to implementation. The county does not use eminent domain to acquire easements and is not yet in the business of compensating property owners for easements. Because most of the high-priority projects have significant private property elements, the county is considering purchasing land in the future.

Charlotte-Mecklenburg Storm Water Services is funded in part through a stormwater fee based on the area of impervious surface. Revenues from the stormwater fee are dedicated to CIP funding. To implement LID/GI, the county leverages CIP dollars to obtain additional funds from various state and local sources, such as the state's 319 grant program, the State Clean Water Management Trust Fund, North Carolina Ecosystem Enhancement Program, and a local mitigation bank. The county has also received American Recovery and Reinvestment Act funds to implement a stream restoration project.

Role of economic analysis

To prioritize stream restoration and BMP projects in the McDowell Creek watershed, the county conducted a cost-effectiveness analysis to determine cost per pound of sediment saved for various LID/GI program components. The analysis provides planning-level estimates intended to provide direction on implementation decisions to determine which projects will provide the greatest benefits for the least cost.

The county does not conduct economic analyses of its reforestation projects. Because reforestation is relatively inexpensive but offers large benefits in terms of air quality and storm water management, the county has simply committed to making reforestation a priority.

Economic analysis method and results

Method: The county prepared a detailed cost analysis of BMP installation, minor system stream enhancement/restoration, and major system stream enhancement/restoration in the McDowell Creek watershed. The results of this analysis were distilled down to a cost per pound of sediment removed in order to compare stream restoration to BMP installation. The cost estimates developed reflect capital costs, including costs associated with project design and planning. The analysis does not include O&M costs or the cost of acquiring land or easements.

For stream restoration, e.g., natural bank stabilization, riparian restoration, and in-stream projects, the county used comprehensive data on loading rates for McDowell Creek based on a Rosgen hydrologic assessment to estimate the sediment savings associated with different projects. Cost estimates are based on a set cost per linear foot of stream restoration which ranged between $95 and a $200 per linear foot depending on the level of restoration or enhancement needed. These costs were generated from “rule of thumb” estimates based on previous county experience with similar types of projects.

The county estimated the cost-effectiveness of proposed retrofit BMPs on the basis of an evaluation of pilot studies implemented in different land use zones that included commercial, high-density residential, medium-density residential, and institutional land uses. From these pilot studies, the county was able to estimate the amount of sediment reduced per acre for similar types of projects, different types of land cover, and cost per acre. The county used this information to evaluate the cost-effectiveness of proposed projects expressed as cost per pound of sediment saved.

Results: The cost-effectiveness of stream restoration and BMP implementation in the McDowell Creek watershed is presented in Exhibit A.8.1.

Outcomes: Results of the analysis indicate that stream restoration is the most cost-effective means of controlling sediment in the McDowell Creek watershed. It is more than two times less expensive to remove a pound of sediment through stream restoration than through the most cost-effective practices, i.e., vegetated swales.

CMSWS also recognizes that other factors such as habitat loss, increases in water temperature, and toxic pollutants such as metals and hydrocarbons are also likely causes of macroinvertebrate population decreases that can be addressed through the use of LID/GI BMPs.

Exhibit A.8.1. Cost-effectiveness of program components in the McDowell Creek watershed

LID/GI component	$ per lb of sediment saved
Major system stream restoration/enhancement[a]	1.02
Minor system stream restoration/enhancement	0.60
Sand filter	24.43
Wet pond	35.15
Wetland	50.33
Rain garden	19.55
Extended detention	69.60
Vegetated swale	3.89
Filter strip	6.23
Pond retrofit[b]	1.88

a. It is important to note that for many communities, stream restoration will not always be the most cost-effective solution because although it reduces the amount of sediment entering the stream, it does not reduce stormwater runoff volume and other entrained pollutants.
b. A pond retrofit is essentially an upgrade of an existing impoundment to improve its water quality performance or increase flood control benefits through the retrofit of a riser or a littoral shelf and/or the modification of the berm forming the impoundment.

Lessons learned and next steps

The county would like to obtain better estimates of the O&M costs associated with different types of projects. This is particularly important because in some jurisdictions, the county is beginning to take over the maintenance of projects constructed by private entities. For example, there are many instances where a homeowners association may not fund the necessary operation and maintenance activities to ensure that the community's stormwater systems are functioning optimally. By assessing O&M costs for specific LID/GI designs, the county can modify design standards to minimize these costs.

In terms of the overall program, the county has learned to manage public expectations associated with different projects by creating a very clear and transparent implementation process. The county strives to be very clear and up front about individual projects and impacts on the landowner or public. For example, with any stream restoration project, some tree loss will typically occur. The county has learned that this can understandably be an issue of concern for some landowners. The county takes great care at the outset of each project to work with landowners and the public to explain any tree loss that will occur.

In addition, the county has learned to take the lead in acquiring easements. In some cases, the county begins the process with the landowner years before a project is scheduled for implementation. The county is always looking toward the next step.

For the most part, the program enjoys public support. Communities and businesses are starting to approach the county about implementing projects on their properties. With each project, however, an educational process must occur. The loss of property, or use of property, is a recurring issue that must be addressed.

Finally, the county has shifted its culture to move from implementing opportunity-based projects to implementing need-based projects. This includes looking at a number of drivers for implementation and pursuing projects that will provide the largest benefits.

Related links

Examples of similar programs and analyses

The City of Austin, Texas, also prioritizes LID/GI-based projects based on cost per pound of sediment reduced. For more information on Austin's stormwater program, see http://www.austintexas.gov/sites/default/files/files/Watershed/riparian/SR-12-13-Riparian-Restoration-Prioritization-Methodology.pdf

Key sources

For more information on projects implemented or planned for implementation in Mecklenburg County, see the Charlotte Mecklenburg Storm Water Services project website: http://charmeck.org/stormwater/Pages/default.aspx

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A.9 Portland, Oregon: A Benefit-Cost Analysis Provides the Basis for Incentivizing Ecoroof Construction

Entity

Name: Portland Bureau of Environmental Services (BES).

The primary mission of Portland, Oregon's BES is to protect the city's clean rivers through water quality protection, watershed planning, wastewater collection and treatment, sewer installation, and stormwater management. As part of its stormwater management programs, BES has implemented the Sustainable Stormwater Management Program, which focuses on green infrastructure initiatives, including the Ecoroof Program.

Population served: 550,000 (estimated)

Community area: 145.4 square miles

Project highlights

- An analysis of ecoroofs versus conventional roofs in Portland demonstrated sufficient public benefits to help justify the adoption of an incentive program to encourage private construction and continue a policy of requiring ecoroofs on city-owned construction projects. Portland's ecoroof program began in 2001. As of 2008, eight city buildings had ecoroofs totaling 30,000 square feet, and there were more than 1 million square feet of ecoroofs and roof gardens within the City of Portland.
- Benefits to building owners were found to be significant, but they do not accrue until sometime after year 20. By year 40 the city estimated that the owner of a building with an ecoroof would save a total of $400,000. Given that this longer-term payback may not be sufficient incentive for developers to build green roofs, the city has provided incentives to help offset the initial higher costs of ecoroofs. The extended life of ecoroofs as compared to conventional roofs also helps make the economic case for ecoroof construction.
- A wide array of benefits was identified, and some were quantified and/or monetized. Even though all of the ecological benefits were not monetized, the analysis shows economic benefits accrue from ecoroof implementation.
- Other communities can use this analysis to assess the benefits of ecoroofs for improving the livability of cities and managing stormwater runoff to achieve multiple benefits, including cost savings.

Background

Portland receives an average of 37 inches of precipitation per year, which creates an annual volume of stormwater runoff of about 10 billion gallons. This runoff can cause flooding and erosion, destroy natural habitat, and contribute to CSOs. BES has developed a stormwater management program that recognizes the need for internal coordination and the promotion of

sustainable stormwater management systems throughout the entire city. It also helps the city meet its Municipal Separate Storm Sewer System (MS4) Discharge Permit, address CSO events, maintain water quality, and control flooding. The Ecoroof program is one of several strategies that Portland is implementing to address these issues.

Types of low-impact development/green infrastructure solutions

Ecoroofs are one of many city-wide solutions that include green streets, sustainable stormwater BMP monitoring, school BMPs, and a financing program. Ecoroofs are well suited to Portland's climate, which includes frequent storm events. BES has provided design standards for ecoroofs that are appropriate for Portland's climate. The ecoroof design standard includes a moisture mat, a protection board, a 5-inch growing medium, gravel drainage, a simple irrigation system, and plants such as sedums, grasses, and wildflowers.

Program description

BES encourages the construction of green roofs because of the multiple benefits green roofs provide. The city incentivizes green roofs by offering developers floor area bonuses, which allow additional building space if an ecoroof is installed in proposed buildings within the Central City Plan District. The Portland City Council also adopted a policy that directs other city departments to incorporate green building practices in all city-owned facilities and buildings. First adopted in 2001, the City of Portland Green Building Policy was re-passed in 2005 and again in 2009. The policy specifically requires an ecoroof design and construction on all new city-owned facilities and all roof replacement projects when technically feasible. Although each department is responsible for its own buildings, the departments may not use cost as a reason to avoid the construction of an ecoroof. To deal with department budget concerns, the program provides funding for stormwater management projects, including ecoroof projects, through various grant and matching grant programs.

The BES also uses other forms of funding for its ecoroofs and other sustainable stormwater management practices. For example, federal grants are used for Innovative Wet Weather Projects. In addition, the BES Watershed Services Division administers Community Watershed Stewardship Program grants for community-proposed projects and Watershed Investment Funds and the Office of Sustainable Development offers Green Investment Funds.

Role of economic analysis

In 2008 BES completed a *Cost Benefit Evaluation of Ecoroofs*, which built upon previous investigations of the benefits of ecoroofs. This evaluation documents the costs and benefits of ecoroofs with the goal of using this information to help increase the construction of ecoroofs throughout the city. The costs and benefits identified in this evaluation show that over a 40 year useable lifesplan, investment in ecoroof construction generates significant benefits to developers and building owners. Analysis also shows that the SW and environmental benefits start accruing immediately upon construction of the practices. BES also has found that documenting the benefits of green roofs is an important way to encourage development of ecoroofs in the city. The driving factor in convincing developers and building owners to construct ecoroofs is that

ecoroofs have twice the lifespan of conventional roofs, i.e., 40 years in comparison 20 years. Developers also can realize energy savings and stormwater reduction benefits.

Economic analysis method and results

Method: The BES conducted a full benefit-cost analysis that included a TBL analysis of a hypothetical, new five-story commercial building with a 40,000-square-foot roof in downtown Portland. BES performed an extensive literature review to identify and quantify the performance, costs, and benefits of this ecoroof. Where possible, BES used its own stormwater monitoring data and infrastructure cost data to develop costs and benefits. When quantitative information was unavailable, the analysis summarized relevant qualitative information.

The analysis examined the increased costs of roof construction and O&M. Benefits quantified in the analysis include:

- Reduced stormwater quantity.
- Avoided stormwater infrastructure.
- Reduced stormwater system management costs.
- Reduced stormwater fees.
- Reduced infrastructure costs.
- Reduced energy demand.
- Reduced heating, ventilating, and air-conditioning (HVAC) equipment size.
- Reduced energy costs.
- Reduced carbon emissions.
- Improved air quality.
- Enhanced habitat.
- Improved roof durability.

In addition, BES identified, but did not quantify, the following benefits of ecoroofs:

- Increased floor area ratio density bonus potential and expedited permitting.
- Reduced basement flooding.
- Reduced stream restoration/mitigation improvements.
- Reduced stream degradation and improved natural hydrology.
- Improved water quality.
- Reduced urban heat island effects.
- Enhanced carbon sequestration.
- Enhanced aesthetics and greater green space recreational opportunities.
- Increased property values and associated increased tax revenues.
- Reduced building insulation cost and improved acoustical insulation.
- Reduced roof reflectivity and associated urban heat island effect.
- Reduced system development charges and permit fees.

BES plans to further improve its analysis by developing the monetized benefits of increased habitat, reduced urban heat island effects, and enhanced carbon sequestration.

Results: BES calculated the net present value (NPV) of its ecoroof program to the public, i.e., the public stormwater system and the environment to private property owners, e.g., developers and building owners, and to a combination of both public and private stakeholders. Based on this analysis, BES concluded that the construction of ecoroofs provides both an immediate and a long-term benefit to the public (Exhibit A.9.1). At year five the net present benefit is $101,660, and at year 40 the net present benefit is $191,421. For building owners, the benefits of ecoroofs do not exceed the costs until year 20, when conventional roofs require replacement. In the long term (over the 40-year life of an ecoroof), the net present benefit of ecoroofs to private stakeholders is more than $400,000.

Exhibit A.9.1. Summary of ecoroof costs and benefits

	Costs		Benefits		Summary	
Focus area	**One-time**	**Annual**	**One-time**	**Annual**	**5 year NPV (2008)**	**40 year NPV (2008)**
Public costs and benefits						
Stormwater management						
Reduced system improvements			$60,700		$60,700	$60,700
Climate				–	–	–
Carbon reduction				$29	$145	$845
Carbon sequestration				–	–	–
Improved urban heat island[a]				–	–	–
Improved air quality				$3,025	$15,515	$104,576
Habitat				–	–	–
Habitat creation			$25,300		$25,300	$25,300
Total public costs and benefits	$0	$0	$86,000	$3,053	$101,660	$191,421
Private costs and benefits						
Stormwater management						
Volume reduction				$1,330	$6,822	$45,866
Peak flow reduction[a]				–	–	–
Energy						
Cooling demand reduction				$680	$3,424	$19,983
Heating demand reduction				$800	$4,028	$23,509
Amenity value						
Amenity value[a]				–	–	–
Building						
Ecoroof construction cost	$230,000				($230,000)	($230,000)
Avoided stormwater facility cost			$69,000		$69,000	$69,000
Increased ecoroof O&M cost		$600			($3,077)	($20,677)
Roof longevity (40-year period)			$600,000		–	$474,951
HVAC equipment sizing			$21,000		$21,000	$21,000
Total private costs and benefits	$230,000	$600	$690,000	$2,810	($128,803)	$403,632
Total costs and benefits					($27,143)	$595,053

a. The economic literature reports that an ecoroof can provide these economic benefits; however, data that would allow the calculation of a dollar amount for these benefits for an ecoroof in Portland are unavailable at this time.
Source: City of Portland, Bureau of Environmental Services. 2008. *Cost Benefit Evaluation of Ecoroofs*.

Outcomes: As of 2008, eight city buildings had ecoroofs totaling 30,000 square feet. There are more than 1 million square feet of ecoroofs and roof gardens in the City of Portland, and this number is growing. Nevertheless, the *Cost Benefit Evaluation of Ecoroofs* report concluded that the city might want to evaluate additional ecoroof incentive options for developers to further encourage ecoroof implementation.

Lessons learned and next steps

BES has been able to quantify many of the ancillary benefits of ecoroofs and has found that publicizing these benefits presents a more convincing argument for the program than simply describing the importance of stormwater management. The most effective driver in convincing the construction industry, developers, and others to construct ecoroofs is the extended life of an ecoroof—40 years—as compared to the 20-year life of a conventional roof.

Constraints faced by BES include difficulties in extrapolating findings from the literature to the City of Portland and monetizing benefits. BES hopes to monetize other benefits (e.g., from carbon sequestration, reduced heat island effects, and increased habitats) in future studies.

Related links

Similar programs and analyses

Seattle, Toronto, and Vancouver have all conducted similar analyses of green roofs. For more information, visit the links below.

Seattle: http://www.seattle.gov/DPD/GreenBuilding/Resources/TechnicalBriefs/default.asp.

Toronto: http://www.toronto.ca/greenroofs/index.htm.

Vancouver: http://vancouver.ca/olympicvillage/greenbuilding.htm.

Key sources

City of Portland, Bureau of Environmental Services, Sustainable Stormwater Management Program overview is available: http://www.portlandonline.com/BES/index.cfm?c = 34598.

City of Portland, Bureau of Environmental Services. April 2008. *Cost Benefit Evaluation of Ecoroofs*. Available: http://www.portlandonline.com/bes/index.cfm?a=261053&c=50818.

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A.10 Philadelphia, Pennsylvania: A Triple-Bottom-Line Analysis of Combined Sewer Overflow Control Options

Entity

Name: Philadelphia Water Department (PWD), Office of Watersheds (OOW)

OOW is a unit of PWD's Planning and Engineering Division and is responsible for PWD's Combined Sewer Overflow (CSO), Stormwater Management, and Source Water Protection programs.

Population: 1.5 million

Area: PWD's CSO program area covers about 63 square miles within the City of Philadelphia. The boundaries of the CSO area fall within the watersheds of Tacony-Frankford Creek, Cobbs Creek, the Lower Schuylkill River, and the tidal portion of the Delaware River Watershed.

Project highlights

- *Full and fair comparison of green vs. grey infrastructure for stormwater management.* This comparison was needed to evaluate the best approach for investing the city's funds to solve the CSO problem in a dense urban environment.
- *Triple-bottom-line (TBL) analysis.* Financial, social, and environmental considerations provide insight into the wide array of benefits of GI for urban residents and help guide the city to obtain the best value for its residents.
- *Greater benefits of LID/GI*. The TBL analysis demonstrated that, in Philadelphia, for equal investment amounts and similar overflow volume reductions, supplementing gray infrastructure with GI provides many times the benefits in economic value, recreational opportunities, ecosystem enhancement, and reduced construction impacts, compared to a single-purpose investment in traditional stormwater infrastructure.
- *A model for communities to identify and value LID/GI amenity benefits*. Realizing the benefits achieved by GI in urban redevelopment and retrofits can help communities decide on their own future stormwater management investment approaches.

Background

CSOs are a primary source of pollution to Philadelphia's waterways. During heavy rainfalls or sudden snowmelts, overflows can occur in various locations throughout the city, at any of the 164 permitted CSOs. Overflows from combined sewers can exceed water quality standards, threaten aquatic life and habitat, and impair the use and enjoyment of the water body.

Water quality impairment during dry weather, along with limited public awareness and sense of stewardship, is also a major concern. Common types of impairment include high levels of fecal coliform, elevated water temperatures, and dissolved oxygen levels below minimum standards.

Another concern is the presence of litter and unsightly streams, which discourages recreational use.

In the Tookany/Tacony-Frankford and Cobbs Creek watersheds, degraded aquatic and riparian habitats and limited diversity of fish and other aquatic species pose overlying ecosystem concerns. In these watersheds, bank and streambed erosion threaten the functions of nearby utilities, and CSOs impact both water quality and stream channel stability. In the Schuylkill and Delaware River watersheds, major concerns include the lack of recreational opportunities and public access to the riverfront and the presence of polychlorinated biphenyls, which has led to fish advisories.

Types of LID/GI solutions

PWD is committed to the development of a balanced "land-water-infrastructure" approach to achieve its watershed management and CSO control goals. This method includes traditional infrastructure-based approaches, as well as a range of land-based stormwater management techniques and physical reconstruction of aquatic habitats. Together, these approaches form the basis for PWD's *Green City, Clean Waters* program.

Land-based stormwater management approaches can be used to restore a more natural balance between stormwater runoff and infiltration, reduce pollutant loads, and control runoff rates at levels that minimize streambank erosion. Specific approaches include disconnection of impervious cover, bioretention, subsurface storage and infiltration, green roofs, swales, green streets, permeable pavements, and urban tree canopy.

Water-based approaches include bed and bank stabilization and reconstruction, aquatic habitat creation, plunge pool removal, improvement of fish passage, and floodplain reconnection. Restoring designated uses and ultimately removing streams from the state's list of impaired waters will require restoration of functions the healthy aquatic ecosystem once provided. These functions may be impossible to restore without restoration of physical channel and habitat characteristics required to support them.

Program description

PWD's *Green City, Clean Waters* program is designed to provide many benefits beyond the reduction of CSOs. The ultimate goal of PWD's approach is to regain the aquatic and riparian resources in and around streams that have been lost due to urbanization in and around the City of Philadelphia, while achieving full regulatory compliance in a cost-effective manner.

With this vision, PWD has reduced capital investments that are typically implemented out of the public view, i.e., underground or in pipes and instead redirected funds to the implementation of LID/GI techniques. Central to this strategy is a commitment to city greening, sustainability, open space, waterfront revitalization, outdoor recreation, and quality of life.

Based on the land-water-infrastructure approach detailed above, specific implementation strategies include:

- On public lands, large-scale implementation of green stormwater infrastructure to manage runoff at the source and reduce demands on sewer infrastructure.
- On private lands, requirements and incentives for green stormwater infrastructure.
- A large-scale street tree program to improve aesthetics and manage stormwater.
- Stream corridor and waterfront improvements to increase access to and improve recreational opportunities.
- Preservation of open space and the management of stormwater at its source.
- Conversion of vacant and abandoned lands to open space.
- Redevelopment of abandoned lands and brownfields using up-to-date stormwater management techniques to reduce runoff.
- Restoration of streams using physical habitat enhancements that support healthy aquatic communities.
- The addition of grey infrastructure when necessary to meet appropriate water quality standards and flood control needs.

Role of economic analysis

PWD's proposed CSO program will result in multiple social and environmental benefits, e.g., public health, recreation, housing and property value benefits, that compliment improvements in water quality. To gain a better understanding of the total benefits, and to evaluate the use of GI on such a large scale, PWD performed a TBL analysis of various CSO control options.

PWD believed it was important to analyze the TBL benefits in order to obtain a full and fair comparison of the use of GI versus traditional infrastructure alternatives. Understanding the full societal costs and benefits of the program is important in justifying the program to ratepayers, who will ultimately pay for this initiative.

Economic analysis method and results

Method: Cost-benefit analysis using TBL accounting of benefits and costs expands the traditional financial reporting framework to take into account the ecological and social performance of each infrastructure option. Thus, the TBL approach provides for a more complete and meaningful accounting of PWD activities that reflects all three bottom lines—financial, social, and environmental.

The TBL assessment provides an evaluation of the "external" costs and benefits associated with various CSO control options. (That is, benefits that "spill over" into other areas besides water quality and costs that are not included in traditional engineering estimates of the expense to build

and operate facilities.) The suite of CSO control options evaluated includes LID/GI-based approaches, as well as traditional infrastructure alternatives, e.g., tunneling; transmission, plant expansion and treatment; and satellite treatment. Each CSO option was evaluated in detail for each watershed.

Key external benefit and cost categories were identified based on the various components associated with each option. Most of the external benefits identified only resulted from the implementation of LID/GI-oriented options and were not realized using traditional infrastructure alternatives. Key benefit and cost categories in the TBL assessment include:

- *Recreation.* The LID/GI-based options will result in additional recreational opportunities due to stream restoration and riparian buffer improvements, as well as a general increase in vegetated and treed acreage in the city.
- *Higher property values*. Trees and plants improve urban aesthetics and community livability. Studies show that property values are higher when trees and other vegetation are present.
- *Heat stress reduction.* LID/GI can create shade which can reduce the amount of heat gain that occurs in urban areas. Vegetation can also emit water vapor which helps to cool air temperatures. This cooling effect is expected to reduce heat stress-related fatalities in the city during extreme heat events.
- *Water quality and aquatic ecosystem improvements.* Watershed restoration efforts under the LID/GI-based options are expected to generate important improvements to riparian and water-based resources.
- *Wetland creation and enhancement.* The watershed restoration efforts are expected to create or enhance more than 190 acres of wetlands in the relevant watersheds. Additional and enhanced wetland acres will provide a range of ecosystem services.
- *Poverty reduction from local green jobs.* GI creates the opportunity to hire local unskilled (and otherwise unemployed) laborers for landscaping and restoration activities. The benefits of providing these local green jobs include the avoided costs of social services that the city would otherwise provide on behalf of the same people if they remained unemployed.
- *Energy savings and carbon footprint reduction.* Green space helps lower ambient temperatures and shade and insulate buildings from wide temperature swings, decreasing the energy needed for heating and cooling. In addition, diverting stormwater from wastewater collection, conveyance, and treatment systems reduces the amount of energy needed to pump and treat the water. Reduced energy demand in buildings, and increased carbon sequestration by added vegetation, result in a lower carbon footprint.
- *Air quality improvements*. Trees and vegetation also improve air quality by filtering some airborne pollutants, e.g., particulate matter and ozone. Reduced energy consumption also results in decreased emissions, e.g., sulfur dioxide (SO_2 and nitrogen oxide (NO_x) from power generation facilities. This can reduce the incidence and severity of respiratory illnesses.

- *Construction- and maintenance-related disruption.* All of the CSO options will result in some level of disruption due to construction and/or program activities. The social costs of disruption can include traffic delays, limited access to places of business, increased noise and pollution, and other inconveniences. Construction activities also will likely result in occasional delays and increased travel times for passenger and commercial vehicle travelers in Philadelphia.

Based on planned program activities, physical outcomes for each benefit/cost category were defined and quantified. Physical outcomes include non-monetary measures of benefits and costs, such as additional recreational visits to a park due to improved riparian areas and stream restoration, or additional time Philadelphia residents are expected to spend in traffic due to traffic disruption associated with the program activities.

Monetary values were assigned to the physical outcomes associated with each option based on standard approaches developed and used by environmental impact and valuation professionals and organizations. Benefits and costs were evaluated over a 40-year planning horizon (2010–2049).

To estimate annual benefits for each year of the planning horizon, a time path was applied to each benefit-cost category to reflect the rate at which benefits and costs are expected to accrue. The time path was based on planned schedules for implementation, construction, and maintenance, and a tree growth model that applies to benefits dependent on the number of additional trees to be planted in the watershed. For example, the benefits associated with air pollutant removal from trees will not be fully realized in the first year of project implementation and will continue to accrue as the trees grow. Thus, the analysis takes into account the percentage of trees planted each year as well as the rate at which the trees grow and mature.

Results: Exhibits A.10.1 and A.10.2 provide a summary of findings for two of the CSO control options under consideration: the 50 percent LID/GI option which assumes that runoff from 50 percent of impervious surface in the City of Philadelphia is managed through GI, and the 30-foot tunnel option which would require the construction of a system of storage tunnels with an effective diameter of 30 feet that would collect runoff from all of the watersheds in the service area. These options were chosen to demonstrate the difference in net benefits between green and traditional infrastructure. The reporting of these results is not intended to indicate that a final PWD decision will be based on these two alternatives.

The results shown below reflect benefits and external costs accrued over the 40-year study period. Exhibit A.10.1 describes the outcomes in terms of the physical outcomes obtained. Exhibit A.10.2 provides the estimated monetary value for these outcomes, in present value (PV) terms (2009 USD). PV estimates are based on an inflation rate of 4 percent and a nominal discount rate of 4.875 percent, applied over the 40-year planning horizon.

O*utcomes*: The key finding of this TBL assessment is that LID/GI provides a wide array of important environmental and social benefits to the community, and that these benefits are not generally provided by the more traditional alternatives.

Exhibit A.10.1. Philadelphia city-wide physical unit benefits of key CSO options: Cumulative through 2049[a]

Benefit categories	50% LID/GI option	30-ft tunnel option[b]
Additional creekside recreational user days	247,524,281	
Additional non-creekside recreational user days	101,738,547	
Reduction in number of heat-related fatalities	196	
Annual willingness to pay (WTP) per household for water quality and aquatic habitat improvements[c]	$9.70–$15.54	$5.63–$8.59
Wetlands created or restored (acres)	193	
Green collar jobs (job years)	15,266	
Change in particulate matter due to increased trees (μg/m^3)	0.01569	
Change in seasonal ozone due to increased trees (ppb)	0.04248	
Electricity savings due to cooling effect of trees (kWh)	369,739,725	
Natural gas savings due to cooling effect of trees (kBtu)	599,199,846	
Fuel used (vehicles for construction and operation and maintenance; gallons)	493,387	1,132,409
SO_2 emissions (metric tons)	(1,530)[d]	1,452
NO_x emissions (metric tons)	(38)	6,356,083
Carbon dioxide (CO_2) emissions (metric tons)	(1,091,433)	347,970
Vehicle delay from construction and maintenance (hours of delay)	346,883	796,597

a. The 50% LID/GI and 30-ft tunnel options were chosen as example alternatives to illustrate the differences between green and traditional infrastructure approaches. This does not imply that PWD has made a final decision regarding the options.
b. 28-ft tunnel option in Delaware River watershed.
c. WTP per household in Philadelphia, Massachusetts, including Bucks, Chester, Delaware, Montgomery, and Philadelphia counties.
d. Parentheses indicate negative values.

Exhibit A.10.2. City-wide present value benefits of key CSO options: Cumulative through 2049 (2009 million USD)

Benefit categories	50% LID/GI option	30-ft tunnel option[a]
Increased recreational opportunities	$524.5	
Improved aesthetics/property value (50%)	$574.7	
Reduction in heat stress mortality	$1,057.6	
Water quality/aquatic habitat enhancement	$336.4	$189.0
Wetland services	$1.6	
Social costs avoided by green collar jobs	$124.9	
Air quality improvements from trees	$131.0	
Energy savings/usage	$33.7	($2.5)
Reduced (increased) damage from SO_2 and NO_x emissions	$46.3	($45.2)
Reduced (increased) damage from CO_2 emissions	$21.2	($5.9)
Disruption costs from construction and maintenance	$(5.6)	($13.4)
Total	**$2,846.4**	**$122.0**

a. 28-ft tunnel option in Delaware River watershed.

Based in part on this evaluation, PWD has determined that a GI-based approach, coupled with targeted traditional infrastructure, is the approach the city prefers to follow. First, PWD believes this type of approach will reduce CSO in a cost-effective manner. Second, it meets the broader goals of PWD's Integrated Watershed Management Approach while maximizing environmental, social, and economic benefits. Third, PWD believes this approach meets all watershed goals without causing severe economic hardship for PWD's ratepayers. In addition, public feedback has expressed a clear and unambiguous preference for an alternative focused on green stormwater infrastructure.

Lessons learned and next steps

Analyses of social and environmental benefits invariably require the use of assumptions and approaches that interject uncertainty about the accuracy or comprehensiveness of the empirical results. The methods and principles employed in PWD's TBL analysis, however, are well-established approaches to quantifying benefits in the field of environmental and natural resource economics. Throughout their analysis, PWD attempted to be explicit and reasonable about the assumptions and approaches adopted. For transparency, the research team identified key omissions, biases, and uncertainties (OBUs) embedded in the analysis, and described how the results of the analysis would likely have been impacted (e.g., whether benefits would have increased, decreased, or changed in an uncertain direction) if the omission or data limitation had been avoidable. In conjunction with the OBU issues, a series of sensitivity analyses were conducted to explore how changing some of the key assumptions would impact findings.

Related links

Similar programs and analyses

Cincinnati, Ohio, is also integrating LID/GI approaches into its respective long-term control plans. For more information on Cincinnati's planned program, see http://www.msdgc.org/downloads/wetweather/greenreport/Files/Green_Report.pdf.

Key sources

For a summary of the TBL report: http://www.phillywatersheds.org/ltcpu/Vol02_TBL.pdf.

For more information on Philadelphia's proposed CSO control program: www.phillywatersheds.org.

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A.11 Kirkland, Washington: Ranking Benefits to Help Assess the Feasibility of LID/GI Approaches in CIP Transportation Projects

Entity

Name: The City of Kirkland Public Works Department, King County, Washington

Population served: 80,505

Area: 18 square miles

Project highlights

- Decision made to incorporate LID/GI elements during the design phase of all CIP (capital improvement program) transportation projects.
- Drivers for the LID/GI program included public support, anticipated permit requirements, and regional experience demonstrated the benefits of LID/GI often outweighed the costs.
- Process established for integration of LID/GI into CIP transportation projects and for coordination between stormwater engineering and capital projects engineering staff.

Development of a project evaluation matrix to compare and quantitatively rank the benefits of LID/GI-based transportation projects. The matrix allows the staff to quickly and easily compare project alternatives using TBL benefit analyses and is especially useful to communities with limited resources.

Background

In 2007, the Kirkland City Council directed city staff to begin looking for ways to expand the use of LID/GI in both public and private developments. A number of factors motivated the city to address LID/GI. A prime driver was political support: The electorate understood the need to take action to protect Puget Sound and local waterways. The council also wanted to proactively prepare for anticipated changes to the National Pollutant Discharge Elimination System Municipal Separate Storm Sewer System permit requirements that were expected to include LID/GI performance requirements. Requirements for LID/GI were also consistent with the sustainable urban development/LID/GI initiatives being implemented by Seattle and other municipalities in the Pacific Northwest. Under this focus, stormwater engineering staff within the Kirkland Public Works Department began to investigate ways to integrate LID/GI into CIP transportation projects.

In the past, opportunities to integrate LID/GI into CIP projects were missed because there was little coordination between the stormwater engineering group and the capital projects engineering group regarding the potential incorporation of stormwater LID/GI practices into the projects. In most cases, the stormwater staff would not find out about CIP transportation projects until it was too late to integrate LID/GI into the project designs. To begin the process of looking for LID/GI

elements that could be incorporated into CIP projects, stormwater staff evaluated the feasibility of integrating LID/GI elements into 10 planned CIP projects. The results of this evaluation are published in the *Low Impact Development (LID) Feasibility Study: Analysis of Opportunities and Constraints to Incorporate LID Elements into Capital Improvement Program (CIP) Projects in Kirkland, Washington* (Leighton et al. 2007). Stormwater staff in the Public Works Department conducted the study with the expectation that the capital projects group would design the projects. The study was a key first step toward integrating LID/GI into CIP projects during the conceptual design phase.

Types of LID/GI solutions

The implementation of LID/GI in Kirkland's CIP projects has focused primarily on the use of on-site BMPs as a component of street reconstruction projects. These BMPs are designed to emulate natural hydrological and ecological processes in order to reduce peak flow and total runoff volume, improve water quality, and save money by reducing the need for regional stormwater facilities downstream. Projects were designed to meet required stormwater flow control criteria, based on the *2009 King County Surface Water Design Manual*. These requirements include matching the 2-year and 10-year peak flow, and matching discharge durations up to the 50-year peak flow. The manual also requires that a minimum of 10 percent of the runoff from the impervious area on-site be managed through LID/GI techniques, as feasible.

The objectives for the 10 projects analyzed in the *Feasibility Study* included the addition and improvement of sidewalks, bicycle lane additions, pedestrian corridor improvements and roadway improvements. The LID/GI BMPs used included:

- Bioretention and biofiltration facilities such as swales, rain gardens, stormwater planter boxes, and tree box filters
- Permeable pavements
- Street lane width reductions.

Program description

Kirkland's LID/GI strategy is to "control the volume of stormwater by integrating site planning and stormwater management from the beginning of the design process of a project to preserve a more hydrological functional landscape" (PSAT and WSU, 2005).

In the CIP transportation context, the goal is to integrate LID/GI into the conceptual design phase of all future projects involving public rights-of-way, when technically feasible. Kirkland uses a number of LID/GI implementation options which are determined by project site characteristics. For example, for a project that would have traditionally called for the installation of a new concrete sidewalk and planter strip, the city might select permeable pavement for the sidewalks, decrease the lane width, and install a rain garden separating the sidewalk and street. The benefits of this design change include a reduction in runoff from the permeable sidewalk and reduced street width, and improved water quality and stormwater flow attenuation from the rain garden.

In general, the CIP projects are funded from four main sources—current revenue, reserves, repaid debts, and external sources. Funding sources for each project vary, and a mix of sources is often used to meet a projected budget. For some LID/GI projects, additional funding may be available through grants or other external sources. For example, the City of Kirkland partnered with King County on a CIP project that incorporated LID/GI elements that were funded by the U.S. EPA (PSP 2010).

Role of economic analysis

As part of the *Low Impact Development (LID) Feasibility Study: Analysis of Opportunities and Constraints to Incorporate LID Elements into Capital Improvement Program (CIP) Projects in Kirkland, Washington,* Kirkland prepared a detailed evaluation of the 10 CIP transportation projects planned for implementation. The primary objective of the analysis was to set up a ranking and selection process for integrating LID/GI into CIP transportation projects. An evaluation matrix was used to evaluate and rank the potential benefits of the proposed LID/GI project designs. Nonstormwater related benefits also were included in the matrix to gain a more complete picture of the benefits that accrue through the use of rights-of-way to achieve multiple objectives. (Leighton et al. 2007).

The feasibility study is not a traditional economic analysis in the sense that the city does not provide costs or monetized benefits for the different projects. However, the ranking matrix provides a way to quantify and rank benefits, taking into account the social, environmental, and financial aspects of the different projects. This type of analysis offers communities with limited resources a way to analyze projects taking TBL benefits into account.

Economic analysis method and results

Methods: Exhibit A.11.1 illustrates the evaluation matrix for two of the 10 projects. As shown in Exhibit A.11.1, the matrix provides information on six attributes for each project:

- *CIP info.* Lists general CIP project information, including project location, funding status, and whether the project will require a right-of-way acquisition.
- *LID/GI approach*. Lists the proposed mix of LID/GI elements for the project.
- *LID/GI criteria.* Includes project-specific cost and effectiveness information for stormwater function, flow control, or treatment comparing the typical conventional CIP project design to the LID/GI project alternative. Capital and maintenance costs were compared.

LEGEND for Matrix Score	
	High
	Moderate
	Low

CIP Info				LID Approach	Low Impact Development (LID) Criteria				
CIP Location (CIP Project Number)	% Funded	CIP w/ ROW acquisition	Stormwater Basin Information	Proposed LID Elements	LID Stormwater Function Flow Control or Treatment Compared to CIP (High = 3, Low =1)	LID demonstration potential (High = 3, Low =1)	LID Element Capital Cost - Compared to "Conventional" Stormwater Management (Low Cost = 3, High Cost =1)	Baseline LID Maintenance needs/costs (Low Cost =3, High Cost = 1)	Cumulative LID Valuation Score High = 12-11 Moderate = 10-8 Low = 7-4
116th Ave. - NE 40th St to NE 60th St. (0001000)	83%	No	Yarrow Creek (Preliminary report for stormwater management requirements being prepared by Perteet)	Swales, Porous Pavement for Multi-use trail, Reduction of Current Lane Widths	High (3) Reduction of impervious surface versus original CIP strategy, Improved water quality treatment, within Sensitive Areas	High (3) LID adjacent to Sensitive areas: Yarrow Creek; Function of LID along a Multi-modal use corridor; Visible to other adjacent property owners: City of Bellevue, State Parks, WSDOT	Low Cost (3) A reduction of new impervious surfaces could reduce or eliminate detention and/or treatment structures	Moderate (2) Increased in some areas due to proximity of Yarrow Creek	11
NE 100th St. (0034000)	100%	No	100th - Moss Bay 116th Ave NE - Forbes Creek (Stream Protection Flow Control)	Rain gardens, Swales, Porous Sidewalks, Reduction of Impervious Surface	Moderate (2) Reduction of impervious surfaces	Moderate (2) Function of porous pavements	Low Cost (3) Difference in cost of concrete vs. porous concrete is not significant.	Low Cost (3)	10

Exhibit A.11.1. Kirkland benefits matrix for evaluating the feasibility of CIP transportation projects.

Source: Leighton et al. 2007.

Other Benefits from Proposed LID Elements								Cumulative Priority Valuation	Collaboration Opportunities	
Ecological: stream, wetland, and/or tree canopy (High = 3, Low =1)	Habitat and Human health (High = 3, Low =1)	Ecological Connectivity (High = 3, Low =1)	Other benefits (High = 3, Low =1)	Comprehensive Plan Framework Goal (FG) Alignments High = 3 Low =1 (See Appendix B)	Encourages Inter-agency Collaboration (High = 3, Low =1)	Promotes System wide Carbon-neutral Patterns (High = 3, Low =1)	Cumulative Benefit Valuation Score High = 21-18 Moderate = 17-14 Low = 13-7	Total LID and Benefits Valuation Score High = 33-28 Moderate = 27-21 Low = 20-11	Possibility of pairing with future redevelopment of adjacent site's)	Possible Public and Private Maintenance Partnerships
High (3) Reduces pollutants and peak flows to Yarrow Creek	High (3) Improve downstream surface water quality	High (3) Stream restoration/ invasive plant removal; improve access to Bridle Trails State Park for equestrians and other users	High (3) Traffic calming via road diet and delineated separation for users	High (3) FG-1, FG-2, FG-5, FG-7, FG-9, FG-10, FG-11, FG-13	Moderate (2) Project may engage Kirkland Planning + Public Works. Possibly Kirkland + WSDOT or WA State Parks	Moderate (2) This project encourages alternative transportation, while using local resources to manage stormwater.	19	30	No	Bridle Trails State Park, Local Equestrian Association, and WSDOT
Low (1) This is an opportunity for a demonstration project	High (3) Improve downstream surface water quality	Low (1)	Moderate (2) LID feature is visible to cyclists and pedestrians crossing over 405 completing a bicycle connection	High (3) FG-1, FG-2, FG-3, FG-5, FG-7, FG-9, FG-10, FG-11, FG-13	Moderate (2) Project may engage Kirkland Planning + Public Works	Moderate (2) This project encourages alternative transportation, while using local resources to manage stormwater.	12	22	No	Adjacent homeowners and surrounding community

Exhibit A.11.1. Kirkland benefits matrix for evaluating the feasibility of CIP transportation projects (cont.).

Source: Leighton et al. 2007.

For each criterion used, the city assigned a numeric rating to each project, based on a scale of high (3), moderate (2), and low (1). These scores were then combined to quantitatively rank the projects in terms of their cost and effectiveness. As shown in Exhibit A.11.1, the range for this cumulative scoring that is shown in the last column of this section is high (12–11), moderate (10–8), and low (7–4). The high, medium, and low scores were qualitative scores, assigned by staff based on best judgment and consensus and knowledge of the sites.

- *Other benefits* Additional LID/GI benefits evaluated in the matrix included ecological function, habitat and human health, ecological connectivity, and alignment with the Kirkland Comprehensive Plan Framework Goals. Projects also were evaluated for how well they encourage interagency collaboration and whether they promote carbon-neutral behaviors such as increased use of pedestrian and bicycle facilities in comparison to increasing street widths for vehicular traffic. These benefits were also scored as high (3), moderate (2), or low (1). The range for the cumulative scoring (shown in the last column of this section) is high (21–18), moderate (17–14), and low (13–7).
- *Cumulative priority valuation.* Provides the cumulative score for the LID/GI Criteria and Other Benefits. The range for the scoring is high (33–28), moderate (27–21), and low (20–11).
- *Collaboration opportunities.* Indicates the potential for Kirkland to engage the community, other agencies, and organizations through the design and maintenance of the proposed LID/GI elements.

Results: Cumulative priority values for the 10 projects ranged from 22 to 30. Five of the projects scored 28 or greater, falling in the high benefits category. The other five projects scored between 27 and 21, falling in the moderate benefits category. When projects were evaluated solely on the LID/GI Criteria, four projects scored in the high benefits category (12–11), three projects scored in the moderate benefits category (10–8), and three projects were in the low benefits category (7–4). The projects that scored in the lowest category had one thing in common—high baseline maintenance costs. In addition, the capital costs for LID/GI stormwater management designs ranged from low (six projects) to moderate (two projects) to high (two projects) when compared with costs for conventional stormwater management.

Outcomes: The project evaluation matrix used in the *Feasibility Study* helped to provide the institutional framework needed to successfully incorporate LID/GI elements into Kirkland's transportation CIP projects. Kirkland Public Works Department staff view the study as an important first step useful in institutionalizing a LID/GI screening and ranking system. Today nearly all CIP projects, both facilities and transportation related projects, contain LID/GI elements. In fact, many of the projects evaluated in the feasibility study were constructed with LID/GI elements.

Today, LID/GI options for CIP projects are investigated as early in the planning phase as possible. The city's capital projects list is developed on a 6-year cycle and is updated every other year. Initial information about each project is included when the project is put on the CIP list, but the specifics are not determined until the year the project comes up for funding. The city project engineer instructs consultants to consider LID/GI in the early design phase.

Lessons learned and what's next

When the first CIP projects with LID/GI components were completed, maintenance and related funding concerns quickly became an issue. The skill set required for maintaining traditional CIP projects differs considerably from the skills needed to maintain LID/GI elements. As a result, resistance from the maintenance staff was a problem. Although this issue has occasionally been addressed by using maintenance staff from the Parks and Recreation Department, Kirkland views the long-term solution to be supplemental training for CIP maintenance staff. So far, there has not been sufficient funding available for this training. Fortunately the city has been able to take advantage of training provided by the nonprofit organization Save the Sound, although training opportunities have been limited due to funding issues.

Another maintenance-related issue that arose was the need for LID/GI specific equipment such as vacuum sweepers to maintain permeable pavements. Without proper maintenance permeable pavements may clog over time and the benefits of the practice will diminish. Unfortunately, the City of Kirkland does not own the appropriate vacuum sweeper and it is uncertain whether the city will be able to properly maintain the permeable pavements. Future decisions regarding the use of permeable pavements will be influenced by this consideration.

The funding of maintenance is a recurring issue. Even though staff may be trained to maintain LID/GI practices many LID/GI components have maintenance requirements that require different practices than do conventional CIP components. For example many bioretention landscapes are designed to be aesthetically pleasing and public works staff may not be trained landscapers. Clogging of such systems requires additional skill sets and resources to maintain the infiltrative capacity of the practices. For CIP projects in residential areas, City of Kirkland has developed partnerships with homeowners' associations (HOAs) to help provide maintenance for these systems. For example, private developers installed 10 rain gardens in the public right-of-way to manage stormwater from a public street installed within the residential plat (Garden Gate). The HOA provides basic plant maintenance and upkeep to ensure proper function. When HOAs do not exist, the City attempts to get adjacent property owners to perform the plant maintenance. Although the adjacent property owners are legally required to maintain these areas, effective rain garden maintenance has been a challenge for Kirkland. Despite these issues, Kirkland has learned and continues to learn about best practices for implementing LID/GI techniques. The city supports and advocates for this approach.

Key sources

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A.12 Seattle, Washington: Using an Asset Management Approach for Optimizing Green Stormwater Infrastructure Application

Entity

Name: Seattle Public Utilities (SPU)

Population served: SPU is a municipal utility that provides water to more than 1.3 million customers in King County, Washington, and provides essential sewer, drainage, and solid waste services to about 850,000 City of Seattle residential and business customers.

Area: The city of Seattle is 88.5 square miles, not including water areas.

Project highlights

- SPU reports its Natural Drainage System (NDS) assets, e.g., rain gardens and bioswales in adherence to the Government Accounting Standards Board Statement 34 (GASB 34) basic financial statements for state and local government reporting. This enables SPU to show an increased dollar value of assets from the investment in green stormwater infrastructure (GSI), which supports SPU's capacity to fund expenditures from the capital budget. Reporting under GASB 34 also enables SPU to capture the value of these GSI assets, and make the financial benefits of LID/GI more explicit when planning for future expenditures. Higher asset value can help result in higher bond ratings, which can enable a utility to reduce the costs of borrowing funds and help pass lower costs onto customers.
- The use of GSI is required by Seattle's Stormwater Code for all projects "to the maximum extent feasible." This requirement has led to improvements in the cost-effectiveness of GSI as design improvements have been made over time.
- SPU manages its GSI projects in coordination with its entire suite of stormwater infrastructure, balancing the risks between minimizing life-cycle costs and achieving established service levels across all assets. As part of this asset management process, SPU conducts business case analyses of all GSI projects.
- SPU is collecting data on the capital costs, O&M costs, and benefits of its GSI projects. It uses and builds upon this information when analyzing new projects.
- SPU has engaged scientists from the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration (NOAA) to conduct monitoring at its Venema Creek NDS project site to quantify the ability of the project to improve water quality, flow, and habitat in an urban creek. This information is intended to enable SPU to strategically select NDS sites and allocate resources in the future.

Background

The primary environmental concerns facing SPU's drainage and sewer system department are the significant impairment of Seattle's receiving waters and aquatic life from CSOs and

stormwater runoff. In terms of aquatic life, a key issue is salmon habitat restoration: Two runs of Puget Sound Chinook salmon that pass through Seattle waters were declared threatened under the Endangered Species Act in 1999, and SPU has more recently found high Coho pre-spawn mortality rates in the city's creeks. Flooding of roadways and property from increasing runoff is also a primary concern (City of Seattle, undated).

The City of Seattle has three different types of storm drainage systems, each of which serves about one-third of the city's area. Combined sewers serve the downtown area and the inner neighborhoods that surround the downtown. Separate sanitary sewers and stormwater pipes serve neighborhoods outside the downtown area that were part of the city prior to 1950. The north end of the city, which was annexed to the city in 1954, has no formal storm drainage systems. In this part of the city, stormwater runoff flows to urban creeks, lakes, and the Puget Sound (City of Seattle, undated).

SPU has developed a comprehensive GSI program to address stormwater management throughout these areas of the city. The program includes:

- *NDS projects*. SPU's NDS projects are aimed at recreating the natural drainage performance of pre-development pasture conditions within existing city neighborhoods. NDS limit the negative impacts of CSO and stormwater runoff by redesigning residential streets to take advantage of plants, trees, and soils to clean runoff and reduce stormwater flows. SPU tested its NDS program with the Viewlands Cascade pilot project in 2000 and the Street Edge Alternatives (SEA Street) pilot project in 2001. SPU has now constructed six NDS projects throughout the city and is in the design phase or preliminary engineering phase for three other projects (Valentine, 2007; Tracy Tackett, SPU, personal communication, November 7, 2011).
- *GSI for Stormwater Code compliance*. The City of Seattle's Stormwater Code requires the implementation of GSI for all projects "to the maximum extent feasible." This means that GSI must be incorporated throughout the project site, constrained only by the physical limitations, practical considerations of engineering design and necessary business practices, and reasonable financial considerations of costs and benefits (SPU 2011b).
- *Residential Rainwise program.* SPU's Residential Rainwise program has been developed to encourage residential customers to take steps to reduce the volume of stormwater sent to public conveyance systems by implementing measures such as constructing rain gardens, installing permeable pavements and cisterns, disconnecting downspouts, and improving soil with compost.

In addition, SPU is revising its Long-Term Control Plan, which will define CSO reduction projects to be completed between 2016 and 2025 and identify additional projects for which GSI can be implemented.

SPU's primary revenue source for stormwater management activities is a drainage fee, which appears on property tax bills. Single-family and duplex properties smaller than 10,000 square feet pay an annual fee based on parcel size category. The annual fees for larger family and duplex properties and commercial properties are established per 1,000 square feet based on categories of the percentage of impervious surface (SPU 2011c).

Since 2002 SPU has used an asset management approach for managing infrastructure and making resource allocation decisions within each of its four lines of business (wastewater, drinking water, solid waste, and drainage). SPU defines asset management as "meeting agreed customer and environmental service levels while minimizing life cycle costs" [SPU undated (a)]. SPU's asset management process allows the utility to make decisions in a transparent manner, informed by life-cycle and TBL costs and benefits. By integrating GSI projects into the asset management process, SPU can manage these projects in coordination with its entire suite of stormwater infrastructure, balancing the risks between minimizing life-cycle costs and achieving established service levels across all assets.

Types of LID/GI solutions

Seattle's GSI program include a wide range of LID/GI measures, including permeable pavements, removal of impervious surfaces, rain gardens, planting trees, green roofs, green alleys, swales, cascades (a series of shallow, rock-bottomed pools that step gradually down the slope behind a series of dams designed as weirs to temporarily detain flow within each swale), use of compost-amended soils, and rainwater harvesting.

Program description

This case study illustrates how SPU utilized asset management approaches and integrated them with the GSI and NDS programs to determine the cost effectiveness of GI approaches in Seattle neighborhoods that do not have formal stormwater drainage systems. SPU developed its asset management program based on information obtained from Australian and New Zealand utilities, which pioneered asset management which are now considered best practices. Exhibit A.12.1 summarizes the key aspects of SPU's asset management program which have been embedded into all aspects of the utility's funding decisions for projects. Under this program, SPU requires a business case study for both capital and O&M projects greater than $250,000. The SPU Asset Management Committee reviews projects estimated to cost $250,000 to $1,000,000 and determines whether to approve them. A Corporate Asset Management Committee reviews and approves projects with costs greater than $1,000,000.

Exhibit A.12.2 summarizes the key contents of a typical SPU business case study. The type of economic analysis conducted and specific metrics evaluated as part of the business case study tend to vary by project. For example, a cost-effectiveness analysis is typically conducted for projects that are required under state and federal regulations or must occur in order to maintain a core service of unquestionable value (i.e., projects that "must be done") and projects where all the options being considered provide the same function and value. A benefit-cost analysis is conducted for projects that do not meet these two criteria. Benefit-cost analyses typically involve estimating the net present value of each option under consideration. In general, the analysis includes an in-depth cost analysis of options, quantification of risks and environmental benefits, and identification (but usually not quantification or monetization) of social benefits [SPU undated (b); Terry Martin, SPU, personal communication, May 31, 2011].

Exhibit A.12.1. Key components of SPU's asset management program

1. Define service levels
2. Learn about risk
3. Focus on life-cycle costs
4. Use TBL analysis
5. Optimize data and data systems
6. Create plans for each asset category
7. Clarify roles and responsibilities
8. Use Asset Management Committee to make big investment decisions
9. Measure results
10. Participate in industry benchmarking of performance and outcomes

Source: SPU 2011.

Exhibit A.12.2. Contents of a typical SPU business case study

1. Project information
2. Executive summary
3. Budget and completion
4. Key risks and issues
5. Business case
   - Background
   - Objective
   - Options under consideration
   - Economic analysis
   - Recommendation
6. Related documentation

It is also important to note that SPU reports NDS measures such as rain gardens, bioswales, and green roofs but not measures that focus on planting trees or other vegetation in adherence to the Government Accounting Standards Board basic financial statements requirements for state and local governments under GASB 34. It assigns value to its GSI assets in the same way as it does for traditional infrastructure, based on the useful life of the asset and the typical replacement cycle. The value of its GSI assets includes the cost to construct the measure, to put it into the ground, and to landscape the area. Because some percentage of plants are expected to die during the first year, landscaping costs typically include a year of replacement costs for plants. After that time, any plant replacement costs are considered O&M. For traditional assets, SPU bases its

estimates on historical costs. Although SPU has good records on CIP projects, there is not a long history of projects constructed following GSI requirements. Consequently, SPU is working to capture cost data for its new GSI projects (Kathleen Organ, SPU, personal communication, November 16, 2011).

By reporting its GSI infrastructure under GASB 34, SPU can determine whether assets and equity value increased over time. If values increase, SPU's can more easily justify funding GI expenditures using funds from the capital budget. Reporting under GASB 34 also enables SPU to capture the value of these GI assets in its financial reporting process, and explicitly account for the financial benefits of GI when planning for future expenditures (Kathleen Organ, SPU, personal communication, November 16, 2011).

As described above, SPU has conducted several NDS projects. The Venema NDS project provides a good case study example of how SPU integrated GI solutions into a residential street under the NPS program. Venema Creek is a tributary of Piper's Creek and represents about 85 acres, or five percent, of the Piper's Creek watershed. There is very limited stormwater infrastructure in the area and stormwater runoff flows directly into urban creeks and lakes.

The Venema Creek project design incorporates swales on the downslope of each side of the road right-of-way. Green alleys also can be added where appropriate to compliment runoff reductions achieved through the implementation of the SPU Residential Rainwise program. The goals of the project include:

- Improve the hydrologic flow regime by reducing flow volume and reducing peak flow volume.
- Return the two-year flood frequency event from the current urbanized flow rates and duration to the predeveloped pasture rates and duration.
- Improve water quality to achieve at least 80 percent removal of TSS from the water quality storm event.
- Meet specified stormwater conveyance goals for project streets.
- Improve creek habitat.
- Reduce spot drainage problems.
- Provide stormwater conveyance in an area with no formal drainage infrastructure.

Another key goal of this project is to quantify the ability of NDS projects to improve the water quality, flow, and habitat in an urban creek. The Venema Creek NDS project is the first SPU project to mitigate the majority of stormwater runoff from a single drainage basin in Seattle. SPU has engaged scientists from the U.S. Fish and Wildlife Service and NOAA to conduct monitoring at this site to begin to establish a quantitative relationship between the end-of-pipe performance of NDS strategies on a basin-wide scale and improvement of the water quality, flow, and habitat.

The Venema Creek NDS project is the first SPU project to mitigate the majority of stormwater runoff from a single drainage basin in Seattle.

This information will enable SPU to strategically select sites and allocate resources more cost-effectively in the future.

As part of its business case for the Venema Creek NDS project, SPU identified the key risks associated with the project and developed a response plan for each risk. Exhibit A.12.3 summarizes this analysis. As shown in the table, SPU assigned each risk a probability of occurrence (high, medium, or low) and estimated its potential impact on project cost, schedule, scope, and quality.

Exhibit A.12.3. Key concerns and issues associated with Venema Creek NDS project

			Potential impact			
Risk#	**Description and response plan**	**Probability**	**Cost**	**Schedule**	**Scope**	**Quality**
1	*Description:* Lack of sufficient impervious surface area mitigated in Venema Creek basin to measure the creek's hydrological and biological response. *Response:* Monitoring protocols will be useful. Additional streets could be retrofitted to attain a measurable response.	L	H	L	H	H
2	*Description:* There is strong public opposition to constructing NDS on Palatine Avenue. *Response:* Conduct meetings and site visits with property owners. Continue to secure neighborhood and political support.	M	M	M	M	M
3	*Description:* Risk of O&M budget cut leads to system failure and/or negative community response to aesthetic implications.	L	L	L	L	H
4	*Description:* Negative community response if swales are wet all winter due to extra water diverted to swales. *Response:* Conduct education during design phase to minimize concerns about Palatine Avenue, where the most water will be directed.	L	L	L	L	L

Source: SPU 2010c.

Role of economic analysis

The economic analysis was conducted as part of a business case study to evaluate various options for reducing stormwater runoff and improving habitat and water quality in Venema Creek. This study is part of SPU's asset management process, which allows SPU to evaluate projects in a holistic manner, managing costs and risks across the utility's entire suite of assets, rather than project-by-project.

Economic analysis methodology and results

Methods: SPU conducted a cost-effectiveness analysis to compare the following options for the Venema Creek project:

- *Base Case:* Assumes that the Venema NDS is not implemented, resulting in lost benefits and opportunities.
- *Option 1:* Swales will be constructed on 8.5 blocks with one sidewalk per block.
- *Option 1a:* Option 1 plus construction of three green alleys with permeable pavement.
- *Option 1b:* Option 1 plus construction of seven green alleys and implementation of the Residential Rainwise program.
- *Option 2:* Swales constructed on 8.5 blocks with one sidewalk per block. This option differs from Option 1 in the selection of streets included in the project.
- *Option 3:* Swales on 22 blocks with one sidewalk per block, seven green alleys, and implementation of the Residential Rainwise program.

SPU also compared the costs of the options described above with the costs of three previously completed NDS projects—SEA Street, Broadview, and Pinehurst—as well as with the cost of a "traditional" grey infrastructure system. SPU had developed the traditional cost estimate for an earlier economic analysis that compared an NDS system with a traditional conveyance system and infiltration pond, to achieve comparable stormwater benefits.

To compare the proposed options, SPU first calculated the following environmental benefits associated with improving the Venema Creek habitat:

- Number of "greened acres" (defined as an acre of impervious surface mitigated for stormwater control).
- Percentage runoff reduction.
- Average annual volume infiltrated (million gallons).
- Two-year peak flow reduction (cubic feet per second, or cfs).
- TSS removed (kilograms/year).

Other benefits described, but not quantified or monetized, included:

- Alleviation of severe local drainage problems.
- Collection of scientific knowledge to help SPU improve the cost-effectiveness of its strategic approach to restoring Seattle's watersheds.
- Increased property values estimated at up to 5 percent; however, SPU notes that traditional improvements can also increase property values to some extent.
- Increased neighborhood aesthetics.

SPU then estimated the total project costs, which include capital costs (e.g., construction costs), non-construction or soft costs (e.g., design, project management, construction management, and close-out costs), and O&M costs. SPU estimated low, medium and high estimates of O&M costs for each option based on its experience with other NDS projects and the assumption that SPU will provide 100 percent of the maintenance for the Venema Creek project.

Next, SPU calculated life-cycle costs based on the expected life of each asset and then calculated the present value of life-cycle costs for each option. To compare the proposed options, SPU estimated the present value of costs for three metrics that correspond to primary project goals:

- *Present value of the life-cycle cost per gallon of stormwater infiltrated*, i.e., stormwater volume reduced.
- *Present value of the life-cycle cost per "greened acre".*
- *Present value of the life-cycle cost per kilogram of TSS removed* (note: TSS is also a proxy for other pollutants entrained in runoff.

Results: The results of the SPU analysis are shown in Exhibits A.12.4, A.12.5, and A.12.6. The calculations used for the economic analysis are built, to a certain extent, upon the costs and benefits that were estimated for prior NDS projects.

Exhibit A.12.4 summarizes the environmental benefits quantified by SPU for the Venema Creek options. The differences in environmental benefits that Options 1, 1a, 1b, and 2 provide are relatively small. However, the data shows that the environmental benefits from Option 3 are higher, as is the present value of the costs for this option.

Exhibit A.12.4. Summary of project environmental benefits

Options	"Greened acres"	Runoff reduction (%)	Avg. annual volume infiltrated (million gallons)	2-yr peak flow reduction (cfs)	TSS removed (kg/yr)
1	28.2	81%	19.323	4.4	2,755
1a	28.4 (est.)	[a]	19.453 (est.)	[a]	
1b	28.7	82%	19.649	4.7	2,801
2	27.9	80%	19.095	4.4	2,755
3	30.6	87%	20.92	7.1	2,941

a. Option 1a values are not currently modeled but would be in between Options 1 and 1b. (Note: for all options modeled, the existing average annual runoff is 23.983 million gallons annually and the existing 2-year peak flow is 10.5 cfs.)

Exhibit A.12.5 compares the present value of the costs for each option, two previously completed NDS projects (Broadview and Pinehurst), and the traditional system described above. The costs of the four Venema options range from $7.3 million to $10.8 million. The costs of the Broadview and Pinehurst NDS projects were $7.7 million and $7.0 million, respectively and both were less than the cost of the traditional system which was estimated to be $12.9 million. This cost estimate is based on an economic analysis that SPU conducted of a previous NDS project. The traditional grey infrastructure design was the most expensive option using present value

methods when it was designed to provide equivalent performance in terms of reducing peak flow and volume, improving water quality, and providing street improvements.

Exhibit A.12.6 compares the present value of life-cycle costs for the three cost metrics for each option and for the three previously completed NDS projects. As shown in the table, Option 1 and Option 2 are the most cost-effective NDS options in terms of the three metrics, and these two options are also more cost-effective than the three existing NDS projects. These lower costs are due to design improvements that SPU has implemented since the initial projects, which have resulted in the ability for each swale in the Venema project to handle more flow than in previous projects.

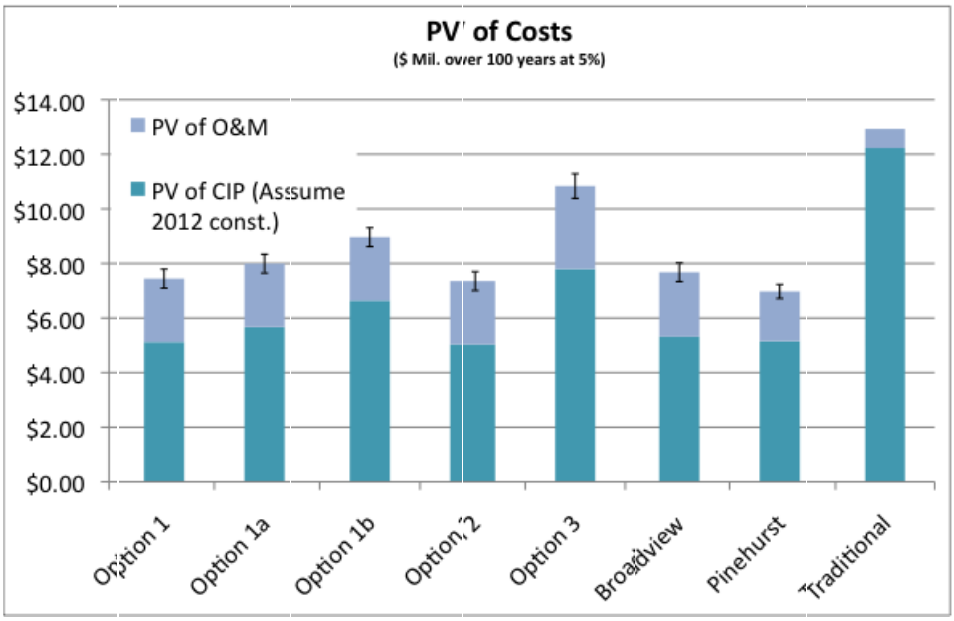

Exhibit A.12.5. Comparison of the present value of capital plus O&M costs for Venema Creek options.

Exhibit A.12.6. Comparison of life-cycle cost metrics for Venema Creek options with existing NDS projects

Options	Cost per gallon infiltrated	Cost per "greened acre"	Cost per kg TSS removed
Option 1	$0.38	$258K	$133
Option 1a	$0.40	$276K	$142
Option 1b	$0.45	$306K	$158
Option 2	$0.38	$258K	$132
Option 3	$0.51	$347K	$182
SEA Street	$1.44	$1.060M	$530
Broadview	$0.60	$511K	$216
Pinehurst	$0.71	$478K	$255

Source: SPU 2010c.

SPU estimated O&M costs based on three years of experience in maintaining the Pinehurst NDS project. The utility found that for the first three years of a project, O&M costs, e.g., planting, mulch, water, weed, trash pickup, soil replacement, are about $3.00 per square foot. From the fourth year on, i.e., the period after the plants are established, O&M costs range from $0.75/square foot to $1.20 per square foot. SPU plans to update these costs in the future based on competitive bidding for the work.

The SPU project team recommended that the utility move forward with Option 1a. The environmental benefits from this option are slightly higher than those for Options 1 and 2 (see Exhibit A.12.4), but Option 1a is slightly less cost-effective than these alternatives (see Exhibit A.12.6). An advantage of Option 1a over Option 1 is that it helps minimize the risk of public opposition to the project by offering improved green alleys as compensation to the residents who will lose a sidewalk and parking spaces as a result of the project.

Outcomes: As a result of the business case evaluation, SPU proceeded with the design phase for Option 1a described above. However, community input obtained during the design process revealed major concerns related to having only one sidewalk per block because in many cases this would require actually removing an existing sidewalk. Among other issues, residents would lose mail delivery if they did not have a sidewalk in front of their houses. Consequently, SPU is reevaluating both its options and its approach to assessing the options in order to place a higher value on social costs and benefits.

Lessons learned and what's next

SPU is continually improving its approaches for quantifying life-cycle costs, O&M costs, and environmental benefits for the various components of its GSI program. The utility expands and builds on these analyses as it develops business case studies for new GSI projects. (See, for example, SPU 2010c and SPU undated (c).) As illustrated above, SPU is experiencing difficulty quantifying and monetizing the social benefits of the program and hopes to expand this analysis in the future. Nevertheless, SPU is working to find ways to place values on the social benefits of its GSI projects. For example, SPU is beginning to use methods for quantifying social impacts compiled by the Center for Neighborhood Technology (CNT, 2010). In addition, SPU recently developed a "multi-objective decision analysis (MODA)" that is primarily used to choose among options for CSO projects where benefits are not easily quantifiable. The MODA approach is a qualitative tool for explicitly assessing and rating the environmental, social, and financial considerations of alternatives in order to obtain a single value or score for each alternative (SPU 2010a; Emiko Takahashi, SPU, personal communication, November 10 and 18, 2011; Tracy Tackett, SPU, personal communication, November 7, 2011).

Key sources and related links

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A.13 Milwaukee, Wisconsin: Optimizing the Potential for Green Infrastructure to Reduce Overflows and Provide Multiple Benefits

Entity

Name: Milwaukee Metropolitan Sewerage District (MMSD)

Population served: 1.1 million customers in 28 communities in Greater Milwaukee

Area: MMSD's service area encompasses 411 square miles that span parts of six watersheds. About 95% of this area is served by sanitary sewers, and combined sewers are used in the remaining area, which is older and more densely developed.

Project highlights

- The city selected GI to reduce combined sewer overflows (CSO) because of the lower costs and resulting ancillary benefits, as outlined in the *Fresh Coast Green Solutions* report.
- An optimization evaluation was performed to investigate the most cost-effective mix of GI solutions for representative watersheds in *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee.*
- The study confirmed the potential of GI to be an important practice that could be used to improve the environmental, economic, and social conditions in the city.
- The approach developed in the optimization study will help the city plan and implement future GI projects in a more systematic and cost-effective manner.

Background

As part of its Water Pollution Abatement Program, MMSD invested $3 billion in collection system improvements to mitigate CSOs over three decades through the mid-1990s. From the late 1990s to 2010, MMSD spent an additional $900 million in grey infrastructure on the *Overflow Reduction Plan* that was developed as part of its *2010 Facilities Plan*.

In the period preceding 1994, which is when the city's Deep Tunnel and other key grey infrastructure improvements became operational, the MMSD sewer system experienced 50 to 60 overflows per year. An annual average volume of eight billion to nine billion gallons of overflow was discharged. Today, that number has been reduced to approximately two overflows per year which discharge on average one billion gallons of overflow per year. MMSD has proposed an ultimate goal of eliminating all sewer overflows by the year 2035. In addition, in the separate sewer service area (SSSA), MMSD is working to improve receiving water quality and reduce the infiltration of stormwater into the sanitary sewer system in order to minimize treatment costs.

To meet stormwater challenges, MMSD will continue to build grey infrastructure. However, as outlined in the City's *Fresh Coast Green Solutions* report, the implementation of LID/GI solutions will be a critical part of the district's plan to reduce and eliminate CSOs, improve water quality, and reduce the amount of stormwater that enters the separate sewer system when it rains. MMSD recognizes that in addition to reducing overflows and improving water quality, LID/GI can offer important environmental and social benefits and help build infrastructure more resilient to climate change.

Types of LID/GI solutions

To date, MMSD has implemented a number of LID/GI projects and programs, including the Green Seams Program, which involves purchasing large areas of land along waterways for preservation and flood control purposes, and a rain barrel program that has resulted in the sale of more than 50,000 rain barrels. Several additional LID/GI demonstration projects, e.g., rain gardens, bioretention, green roofs, have been implemented on both private and public lands. To enhance program effectiveness, MMSD now is focusing on the implementation of a variety of LID/GI strategies, including porous pavement, block bioretention, regional bioretention, rain gardens, green roofs, green alleys, and green streets.

Program description

MMSD began implementing LID/GI in somewhat of a "scattershot approach," by promoting the construction of a variety of projects developed on both public and private lands. MMSD realized that although these projects were successful in reducing stormwater runoff, the utility needed to apply a more structured approach to realize significant progress. Accordingly, MMSD developed the *Fresh Coast Green Solutions* report, which outlined its GI approach, and developed initial information on the costs and benefits of various GI strategies.

In developing *Fresh Coast Green Solutions*, MMSD found that most of the LID/GI strategies under consideration were relatively less expensive than expanding grey infrastructure storage capacity in terms of per gallon construction costs. As part of *Fresh Coast Green Solutions*, MMSD also identified and provided a qualitative ranking of TBL benefits for various LID/GI strategies, based on existing literature.

Subsequent to the development of *Fresh Coast Green Solutions,* MMSD initiated a more detailed analysis of the potential of LID/GI strategies to help eliminate overflows and provide additional benefits. This study, *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee,* was intended to serve as a programmatic document that will help prioritize the implementation of LID/GI throughout MMSD's service area. The economic portion of this study includes a cost-effectiveness analysis and a TBL analysis of various GI practices.

As a result of these planning efforts, LID/GI has been integrated into MMSD's 2020 Facilities Planning Effort, which is based on a watershed approach. Subsequent analyses and related reports will help to further integrate LID/GI into the 2035 or 2040 Facilities Plans and other future planning efforts. As part of its "adaptive management" approach to stormwater management, MMSD plans to continue to evaluate the effectiveness and benefits of LID/GI

practices as implementation becomes more widespread and more is learned about LID/GI implementation.

LID/GI projects installed to date by MMSD have been funded from the same funding mechanism that provides funds for grey infrastructure, i.e., property taxes levied for capital improvements. As LID/GI projects are implemented on a large-scale basis, i.e., from the pilot phase to full implementation, MMSD does not anticipate problems with continuing to use capital funds for implementation.

Role of economic analysis

MMSD's recently completed draft study, *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee,* provides an analysis of the potential of LID/GI to help eliminate overflows and provide additional financial, environmental, and social benefits. The study is intended to help optimize the implementation of LID/GI in both the combined and separate sewer areas of MMSD's service area.

MMSD recognizes that minimizing costs to ratepayers is extremely important. Thus, as a first step to evaluating the potential of LID/GI, MMSD identified through modeling the most cost-effective LID/GI solutions, i.e., optimal combinations of specific LID/GI practices, based on volume reduction potential. This analysis was also used to verify assumptions made in the *Fresh Coast Green Solutions* report regarding the comparison of costs for green and grey infrastructure systems.

MMSD recognizes that moving from a grey to a green and grey infrastructure hybrid system will require community support and strong partnerships. To build this support, MMSD believes that it is important to identify and report on the full spectrum of LID/GI benefits. Thus, as a second step to evaluating the potential of LID/GI, MMSD conducted a TBL analysis to evaluate the range of economic, environmental, and social benefits associated with various LID/GI practices, and to determine the degree to which each of the LID/GI practices contributes to the TBL.

Economic analysis method and results

Method: As a first step in *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee,* MMSD applied the System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) model to a pilot area within the combined sewer service area (CSSA) to identify the most cost-effective set of LID/GI practices in terms of runoff volume reduction.

SUSTAIN is a model developed by the EPA to evaluate alternative plans for water quality management and flow abatement techniques in urban areas. SUSTAIN provides a public-domain tool capable of evaluating the optimal location, type, and cost of LID/GI practices needed to meet water quality goals. For more information on SUSTAIN, visit http://www.epa.gov/nrmrl/wswrd/wq/models/sustain/.

Three sewer sheds were chosen for the pilot SUSTAIN evaluation. These sewersheds were selected because they were considered to be representative of the entire CSSA in terms of soil conditions and topography, and because they include a mix of residential, commercial, industrial, and transportation areas to which a variety of LID/GI practices are applicable.

Next, specific LID/ GI practices, i.e., rain gardens, block bioretention, regional bioretention, bio-swales, rain barrels, green roofs, porous pavement, and green alleys were evaluated for applicability within the pilot area based on an analysis of aerial imagery. The potential locations of each type of LID/GI practice identified from this analysis were digitized in a geographic information system (GIS) to determine the maximum opportunity boundaries to be evaluated by SUSTAIN, e.g., maximum roof area available for conversion to green roofs, area of road available for conversion to porous pavement.

The opportunity boundaries for each type of LID/GI practice were then input into SUSTAIN, which developed a series of LID/GI solutions, i.e., combinations of GI practices, for different levels of volume control and cost criteria. Based on this information, MMSD developed a cost-effectiveness curve for the study area for a representative 10-year period. The cost-effectiveness curve was used to identify cost-effective solutions at different levels of stormwater volume reduction.

The maximum volume control achievable through the use of all potential LID/GI practices within the study area is about 85 percent. However, there is clearly a point above which the marginal costs of additional controls increase dramatically. To further investigate this threshold, four solutions at different intervals along the cost-effectiveness curve were selected for detailed performance evaluation. Key measures for each of the four solutions included percent utilization of different LID/GI practices, runoff volume control, and reduction in peak flow, total suspended solids, total nitrogen, and total phosphorus.

Based on this evaluation, Solution 2 from the SUSTAIN model was selected for further evaluation as part of the TBL analysis. Solution 2, which achieved a 65 percent volume reduction across the sewer shed, requires the addition of 1.1 acres of porous pavement, 2.7 acres of green alleys, 2.2 acres of block bioretention, 850 rain gardens, 2.8 acres of regional bioretention, 1,300 rain barrels, 8.5 acres of roadside porous pavement, and green streets with 2.6 acres of roadside porous pavement and 0.6 acres of rain gardens. These practices drain an impervious surface area of 225 acres.

For the purposes of the quantitative TBL analysis, the team evaluated 11 TBL indicators, as identified in Exhibit A.13.1. Air quality benefits are also qualitatively discussed, as are the benefits of green roofs.

Exhibit A.13.1. TBL indicators evaluated

TBL category[a]	
Economic	Job creation
	Reduced infrastructure costs
	Reduced pumping costs
	Increased property values
Social	Improved quality of life and aesthetics
	Increased recreational opportunities
Environmental	Reduced stormwater volume
	Reduced sediment loading
	Increased groundwater recharge
	Increased carbon sequestration
	Reduced energy use and heat island effect

a. Note that TBL analyses typically have a financial category, rather than an economic category. The economics of a policy or regulation, e.g., in this case the economics of LID/GI, include all three bottom lines: financial, environmental, and social. Financial benefits typically represent costs to a utility—for example, avoided grey infrastructure costs. Even though they are monetized, benefits such as increased property values and job creation are considered social benefits because they provide benefits to the greater community.

In its *Fresh Coast Green Solutions* report, MMSD highlighted 10 types of LID/GI practices that, individually or in combination, could potentially improve stream water quality and reduce treatment costs for the SSSA and the CSSA. In *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee*, these practices were narrowed and simplified for the purposes of modeling. For the TBL reporting, the team analyzed benefits associated with six LID/GI practices (all included in Solution 2):

- Rain gardens.
- Bioretention systems including bioretention cells in the public right-of-way, native landscaping and stormwater trees.
- Bioswales along transportation corridors.
- Rain barrels.
- Porous pavements.
- Green alleys.

MMSD was unable to identify greenway and wetland opportunities in the pilot area which were two green practices identified in *Fresh Coast Green Solutions*. So these two practices are excluded from the detailed quantitative analysis. However, MMSD does provide a general discussion of their benefits. Green roofs also were omitted from the benefits estimation because they were not selected for Solution 2.

For the quantitative analysis, MMSD estimated the increase in property values and job creation associated with LID/GI implementation using benefit transfer techniques. (For example, values for increased property values and job creation were largely based on findings from *A Triple*

Bottom Line Analysis of Traditional and Green Infrastructure for Controlling CSO Events in Philadelphia's Watersheds (Stratus Consulting 2009).) To estimate reduced or avoided pumping and infrastructure costs, MMSD relied on engineering estimates for grey infrastructure stormwater control costs on a per gallon basis.

The social indicator "improved quality of life" is reflected in the estimated increase in property values due to LID/GI implementation. Thus, separate monetary values were not developed for this category. The value of increased recreational opportunities is also partly reflected in the estimated increase in property values. However, many non-property owners will also benefit from these opportunities. To provide a quantitative estimate for increased recreational opportunities, MMSD determined the amount of additional green space that would be available under Solution 2 as a result of green alleys and bioretention areas. Monetary estimates for the benefits of increased recreation (aside from those reflected in property values) were not estimated.

Many of the other environmental indicators, including reduced stormwater runoff, reduced sediment loading, and increased groundwater recharge, were based on outputs from the SUSTAIN model. These benefits were quantified based on relevant non-monetary measures, e.g., acre-feet of reduced runoff, tons of sediment, acre-feet of groundwater recharge. MMSD also used standard evaluation methods to evaluate reduced carbon footprint and reduced energy use resulting from the implementation of LID/GI practices.

The TBL indicators have different time horizons for reporting. Several indicators have a one-time benefit, including increased property values and recreational amenity.[1] Some environmental indicators are more appropriate to report in terms of recurring annual benefits: reduced stormwater runoff, reduced sediment loading, and groundwater recharge. Other indicators have cumulative benefits that are reported over a 20-year horizon, e.g., carbon sequestration, reduced energy costs, reduced pumping costs, and reduced social costs due to job creation. Results for the pilot area are reported below.

In an effort to estimate the TBL benefits for the entire CSSA, the pilot area benefits determined for Solution 2 were linearly extrapolated based on area. A factor of 25 was used to extrapolate the results, derived from the ratio of the entire CSSA area to the pilot area. The extrapolation assumes that land uses, soils, weather, average property values, and the applicability of LID/GI in the rest of the CSSA are identical to those in the pilot area.

Results: This study confirms that a strategic use of LID/GI, along with traditional grey infrastructure, can be an effective method of reducing overflows in Milwaukee. Exhibit A.13.2 presents findings from the pilot area analysis, as well as results for the entire CSSA.

For each benefit evaluated, MMSD shows how each LID/GI practice contributes to the value of the total benefit. Exhibit A.13.3 provides a schematic of how each of the GI practices helps to

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1. Note that when recreational benefits are monetized, they are typically considered to be annual (rather than one-time benefits) because the benefits are experienced as long as the increased recreational opportunities are in place.

create jobs under Solution 2, and Exhibit A.13.4 shows similar information for reducing pumping costs.

Outcomes: The results of the analysis will be used to help select the projects to implement in the future, and to show that using LID/GI is a valid and effective approach. MMSD believes that this report (along with *Fresh Coast Green Solutions*) will help MMSD employees, regulators, and the public to understand the multiple benefits of LID/GI and move it forward. In addition, the Natural Resources Defense Council (NRDC) approached MMSD about working together to build upon their LID/GI planning efforts identified in *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee.* Together, NRDC and MMSD have developed a LID/GI benefits calculator that includes economic and baseline data developed as part of the *Determining the Potential of Green Infrastructure to Reduce Overflows in Milwaukee* study. For more information visit http://www.h2ocapture.com/.

Exhibit A.13.2. Benefits of GI in Milwaukee CSSA in monetary and non-monetary terms

TBL indicator	Pilot area	CSSA
Improved aesthetics and quality of life	$2.7 million property value increase	$68 million property value increase
Job creation	$220,000 reduction in social costs per year, with a present value of $2.7 million over 20 years	$5.5 million reduction in social costs per year, with a present value of $68 million over 20 years
Reduced infrastructure costs	Not reported	66 to 77% reduction in per unit storage costs
Reduced pumping costs	$46,000 present value savings over 20 years	$1.2 million present value savings over 20 years
Increased recreational opportunities	11-acre increase in recreation area through green alleys and bioretention areas	275-acre increase in recreation area through green alleys and bioretention areas
Reduced stormwater volume	435 acre-feet of reduced runoff per year	10,875 acre-feet of reduced runoff per year
Reduced sediment loading	68 U.S. tons per year	1,700 U.S. tons per year
Increased groundwater recharge	406 acre-feet per year	10,150 acre-feet per year
Increased carbon sequestration	Reduction of 156 tons of carbon dioxide (CO_2) over 20 years	Reduction of 3,900 tons of CO_2 over 20 years
Reduced energy use and heat island effect	64,000 kWh reduction in energy use and $3,900 to $5,700 in energy savings over 20 years (due to increased shading)	1.8 million kWh reduction in energy use and $98,000 to $143,000 in energy savings over 20 years (due to increased shading)

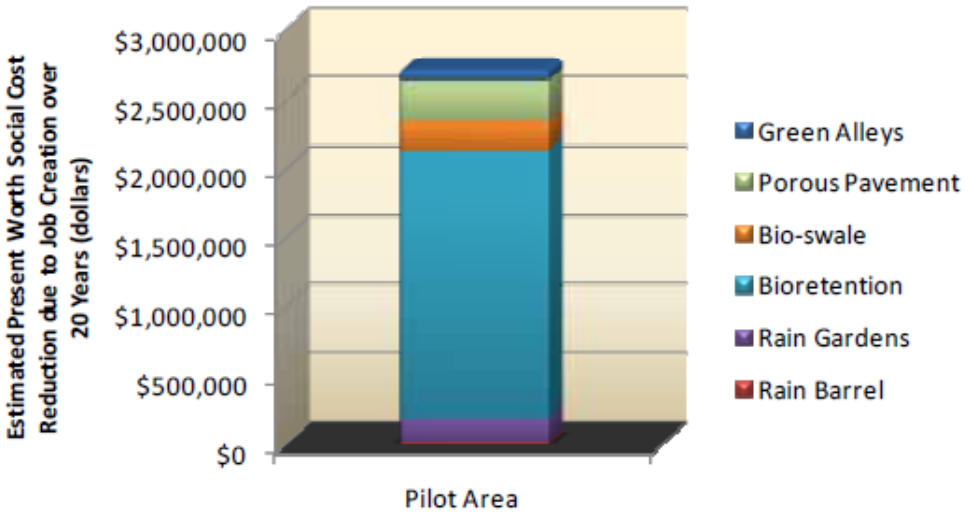

Exhibit A.13.3. Estimated present worth social cost reduction due to job creation over 20 years.

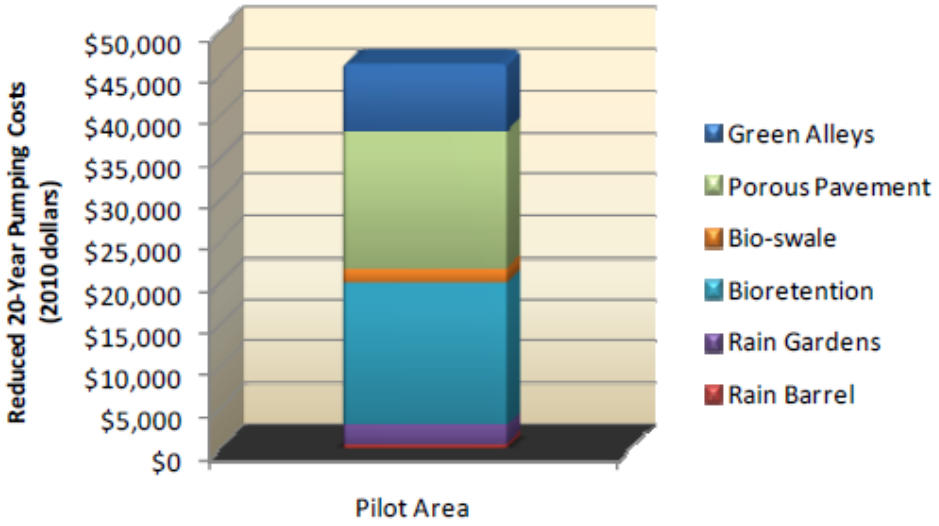

Exhibit A.13.4. Estimated present worth tunnel pumping cost reduction over 20 years.

Lessons learned and what's next

Although the SUSTAIN pilot application was performed on an area within the CSSA, MMSD stresses that GI can have a similar if not greater impact in the SSSA. Each of the practices simulated in SUSTAIN can also be used in the SSSA, and some practices might be even more effective. For example, the pilot SUSTAIN application assumed a residential rain gardens size of 50 square feet in size due to the small yards in the area. To the extent that there are larger yards in the SSSA, which includes more suburban areas that the pilot study, rain gardens could also be designed to be larger. The water quality benefits of LID/GI also will be much more significant in

the SSSA because each pound of pollutant treated is a pound that would otherwise be discharged into the nearest waterway. MMSD's paper, *Why Green Infrastructure and I/I Go Hand in Hand,* provides additional information on the GI issues related to separate sanitary sewers.

When MMSD began implementing LID/GI in 2002, there was not a lot of support within the water and wastewater community or within the district's own utility. Although regulators such as the EPA, the mayor of Milwaukee, and the State of Wisconsin had been supportive of piloting LID/GI, they were not fully on board with the LID/GI approach which was proposed as a substitution for part of the grey infrastructure investment for CSO control.

Gaining internal support was an initial critical concern. However, support has increased over time because of successful demonstration projects, education, and the hiring of staff who support the LID/GI approach. Overall, MMSD recognizes that although reducing overflows and improving water quality is its primary concern, TBL benefits are important and are essential to building public support.

MMSD has learned that valuable public outreach benefits are associated with LID/GI demonstration projects. For example, implementation of a rain garden demonstration project in a public building influenced local residents to install rain gardens in their own yards. Neighborhood associations and schools have also been effective in educating the public.

This process has also educated MMSD in regards to implementing LID/GI on private lands. In many instances private property owners have not maintained their projects. Because of its experiences with BMP maintenance on private property, MMSD now recognizes the need for a formal maintenance agreement with the property owner and regarding how the practice works and how it should be maintained. When implementing projects on private lands, MMSD now enters into an agreement with the property owner that lays out the cost share and post-construction maintenance plan. MMSD has no liability for these projects.

Finally, MMSD has developed a strong GIS program to coordinate its LID/GI efforts. The use of GIS mapping techniques allows MMSD to track all of its projects by LID/GI type and location. In the long term, MMSD's goal is to use GIS to develop a more formal asset management program.

Related links

For more information on MMSD's LID/GI program, see:

- *Fresh Coast Green Solutions:* http://v3.mmsd.com/AssetsClient/Documents/sustainability/SustainBookletweb1209.pdf.
- *Why Green Infrastructure and I/I/ Go Hand in Hand:* http://www.waterbucket.ca/wcp/sites/wbcwcp/documents/media/139.pdf.

For more information on the LID/GI calculator developed by MMSD and NRDC, see http://www.h2ocapture.com/.

For more information on the SUSTAIN model, visit http://www.epa.gov/nrmrl/wswrd/wq/models/sustain/

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